MECHANICAL PROPERTIES AND STRUCTURAL BEHAVIOUR OF MASONRY AT ELEVATED TEMPERATURES

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Notation

A_i = bearing cross area of the wallette

d = density

E_i = modulus of elasticity

f_c = compressive strength

$f_c^{'}$ = normalized compressive strength

$F_{i\max}$ = maximum load applied in the wallette

f_k = characteristic compressive strength

$\dot{h}_{net}$ = net flux for convection and radiation

$\dot{h}_{net,c}$ = net flux for convection

$\dot{h}_{net,r}$ = net flux for radiation

w = dry unit weight

ε_i = strain

ε_m = surface emissivity of the member

ε_f = emissivity of the fire

λ = thermal conductivity

σ = Stephan Boltzmann constant

σ_{co} = yield point

σ_{cu} = compressive ultimate stress

σ_{to} = tensile ultimate stress

α_c = coefficient of heat transfer by convection

ϕ = configuration factor

Θ_g = temperature exposed in the member

Θ_m = temperature in the surface of the member

Θ_f = effective radiation temperature of the fire environment

θ_c = temperature

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Abstract

Masonry is, perhaps, the most effective ancient material that man has employed for construction. One of the first masonry structures built by the man was the pyramid that used to be the most popular construction in Egypt and some parts of America. It occurred approximately 3000 years ago.

Its multi-functional use makes masonry one of the most attractive materials for construction at present. Although a considerable amount of research on masonry in fire started some decades ago, there have been fires that have proved its stability, which for centuries has been considered extremely effective.

Fire resistance is a concept developed by the Russians in approximately 1898. It was originally applied to evaluate the fire performance of concrete structures, but it has been extended to other material construction such as masonry, whose study has been limited to prove its stability when one side only is heated, on walls not greater than 3m height. As a separating element, masonry is dominated by the development of thermal gradients which induce bowing towards the fire side, resulting in what is termed thermal bowing. Masonry can also fail due to large vertical deflections and lateral loads.

As a loadbearing element, masonry requires the compressive strength for design purposes; which varies when masonry is exposed to fire; this is the main aim of the studies presented here. Therefore, the primary investigation consisted of tests on masonry wallettes made with solid lightweight concrete blocks and 1:1:5 mortar proportion to determine the compressive strength at different temperatures, but other properties were also studied such as temperature evolution, modulus of elasticity, modes of failure, and stress-strain relationships. Finite Element Models were also created to simulate not only the identical behaviour of the experimental wallettes but also to predict the behaviour of full size walls exposed to the same thermal conditions. Finally, in order to reproduce the same performance of the masonry components used in the wallettes and to integrate the information into the models, masonry units and mortar specimens were tested in fire under the same conditions as the wallettes.

Declaration

No portion of the work referred to in the thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

Copyright Statement

Acknowledgement

Jesus replied, “You must love the Lord your God with all your heart, all your soul, all your mind. This is the first and the greatest commandment. A second is equally important: Love your neighbour as yourself. The entire law and all the demands of the prophets are based on these two commandments”.

Mattew 22.36

Acknowledgements

It is an honour for me to have been part of Manchester University's community during the last few years. I also feel so fortunate to have been supervised by such brilliant researchers. I wish to express my gratitude and respect to my supervisor Prof Colin G. Bailey, who guided me throughout this adventure. Thanks for your wisdom, for your patience and your friendship. His professionalism has inspired me to develop a range of new skills that will benefit for the future.

This thesis would not have been possible without the financial support of the Mexican Conacyt. Thanks to my great country: Mexico.

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Of course, I would like to show my gratitude to all my family, for their patience and their unconditional love.

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Finally, I thank God for allowing me to have such great and fantastic experiences, for guiding me in the right direction and for blessing me so much in this life.

Chapter 1

Introduction

1.1 Background

Masonry structures are widely used around the world; the most significant evidence that convinces people to use masonry is the existence of historical buildings all over, which demonstrates its capability to withstand severe physical loads. Among the big diversity of benefits, can be listed the low cost, durability, resistance, availability in the market, fire protection, weather protection, sub-division of space, thermal and sound insulation.

Generally, masonry is strong in compression but weak in tension. The compressive behaviour of masonry is of crucial importance for design and safety and has been studied extensively over the years.

After the September 11th 2001 attacks on the World Trade Centre in New York USA causing its collapse, interest has grown in the study of the behaviour of different types of structures subjected to elevated temperatures. This remarkable event has caused researchers to concentrate on examining steel and concrete structures, but recently this interest has been extended to masonry and timber structures. However, knowledge in this area is still considered as limited.

The actual study of masonry structures in fire has focused on determining the fire resistance of walls, for which a considerable variety of materials have been employed. The walls therefore dominate the study of masonry in fire. However, research on other structures such as masonry columns and foundations at elevated temperatures shows an apparent lack of knowledge; further research on this is required to complement the study on masonry in fire.

The performance of masonry walls during real fires has been found to be excellent [1,2]. This has been associated with the exceptional thermal properties of their components, good stability, and lower thermal expansion. Some fire resistance tests have reported that masonry walls fail mainly due to the deterioration of their components and to the occurrence of thermal bowing [3,4,5]. Thermal bowing is an inevitable phenomenon when heating one face of a wall that is not fixed at the top, the hot face will expand more rapidly causing bowing towards the heated side.

The mechanical and thermal properties of masonry constituents have a crucial influence on the behaviour of masonry walls in fire. But research on individual masonry components is required since scientific information on this is insufficient. Nevertheless, some studies carried out on masonry units have reported that they can experience expansion, heat dissipation, loss of strength, loss of water and variation in the thermal conductivity at high temperatures. Additionally, the strength of some types of mortars has been reported [6] to be dependent on material factors such as aggregate, aggregate-cement bond, and thermal incompatibility between components of the composite and properties of cement paste. It also depends on environmental factors including heating rate, duration of the exposure to maximum temperature, cooling rate, loading conditions and moisture regime.

Concrete, as one of the most used block materials for walls, experiences different levels of fire damage; including from minor cosmetic blemishes to external cracking, delamination and spalling, internal microcracking and chemical changes. But the most relevant is the deterioration in mechanical properties as the temperature increases.

This is assumed to be due to physicochemical changes during heating; other factors such as spalling can lead to a loss of material, and a reduction of section size.

In Europe, regulations to determine the fire resistance of structural members are based on prescriptive and performance based methods. EN 1996-1-2 [7] is the leading code to be applied. Most of the fire tests have been carried out on 3m high walls and to limited extent on 2.5m high walls.

A prescriptive fire design method is an approach that evaluates the structural fire response based on material properties, shapes and sizes of elements, thickness of fire protection materials, type of function and construction. This tabulated method expresses the fire resistance periods for the walls.

Although this method is the simplest and cheapest to be implemented, it is in some cases unconservative. Because this method is principally based on standard test results of 2.5m and 3m high walls and it ignores the thermal curvature in walls greater than 3m height. It also omits that standard fires, which are applied in standard fire tests, do not represent a real fire because of duration, intensity and heating rate which can induce a different structural behaviour.

The Performance based method comprises of three assessment methodologies: fire modelling, thermal and structural response. Even though this could be a highly protracted method, it can be structured in such a way that most of the problems could be studied effectively because of the advantages of using sophisticated and powerful software.

The goal of this research work was to determine the reduction of the compressive strength of concrete block masonry wallettes heated at uniform temperatures and to use this data to simulate, by utilising a finite element model, the fire behaviour of full-scale walls heated on one side. The reduction in the strength of the concrete block masonry can be used in design for both uniformly and non-uniformly heated walls.

1.2 Objectives of the research

This research is devoted to investigating the effects of and the variation in the mechanical properties of concrete block masonry at elevated temperatures. The research objectives are detailed as follows:

1- An experimental programme was needed to investigate the mechanical properties from small masonry assemblages known as wallettes. This was mainly focused on the reduction of the compressive strength at 20ºC, 200ºC, 400ºC, 600ºC, 700ºC and 800 ºC.

2- A series of tests on individual masonry units, similar to those used for the wallettes, were required to determine the variation in the compressive strength across the same temperature range as with the wallettes. Tensile mortar tests were also carried out with similar temperatures to in the wallettes.

3- Parametric studies were conducted in order to determine variables that were not covered by the experimental plan. They were used as input data for Finite Element models. Among these variables were emissivity, the stress-strain compressive relationships of mortar at various temperatures, tensile strength of lightweight concrete blocks with temperature, thermal conductivity and heat capacity of mortar and the blocks at elevated temperatures.

4-Once the reduced mechanical properties of individual blocks and mortar were obtained; they were used to develop Finite Element Models to simulate the same behaviour of the experimental masonry wallettes and using these same properties to predict the thermal behaviour of 3m height walls based on standard fire wall tests.

5- Subsequently a validation process was conducted involving the numerical results against the obtained test results.

1.3 Layout of the thesis

This thesis includes six chapters, which are detailed as follows:

-Chapter one is based on the introduction, objectives of the research and a general description of the thesis by chapters.

-Chapter two presents a general literature review covering the effects of elevated temperatures on walls, and their components.

-Chapter three deals with a general description of the experimental plan, including the geometrical and material properties for masonry wallettes; this also contains a description of individual masonry units and tensile mortar tests.

-Chapter four is focused on studying the results obtained from wallettes and their components subjected to ambient and elevated temperatures, focusing on the reduction of the compressive and tensile strengths.

-Chapter five shows the development of Finite Element Models to simulate the behaviour of wallettes and full size walls in fire. It also has a section to validate numerical results against experimental and existing similar results.

-Chapter six presents some experimental and theoretical limitations of this work. It also deals with the most important conclusions and some recommendations for further work.

Chapter 2

Literature review of masonry in fire

2.1 Introduction

Masonry construction has been widely used for many centuries. The continued existence of historical and ancient buildings is the best evidence to demonstrate the durability, resistance against constant weather changes, sound penetration, low cost and availability of masonry. This makes it one of the most important materials for construction at present.

Historical fires [8,9,10] have proved the capability of masonry walls to withstand the effects of high temperatures. Extensive varieties of materials have been proposed for use in masonry structures in fire.

The actual study of masonry in fire is primarily based on standard fire test results. A standard test consists of exposing a masonry member to heated furnace conditions for specific periods. Results expressed in time periods (in minutes) range from 30 min up to 6 hours. Denoted by R30, R60, R90 etc, these periods represent the ability to resist a standard fire before a specified failure criterion is reached. The failure criteria [7,11] for masonry are defined in terms of mechanical resistant (R), integrity (E), insulation (I) and mechanical impact (M).

The masonry standard fire test methods in the UK are based on rules from BS 476-20 [12], BS 1363-1 [11], and ISO 834-8 [13] and their corresponding parts; other aspects dealing with fire are also contained in BS 5628-3 [14]. However, the European EN 1996-1-2 [7] is the current leading code providing three assessment methods to determine the fire resistance of masonry walls: by testing, predefined data or calculation.

Two methods are generally employed to evaluate the fire resistance of masonry walls: prescriptive and performance-based. The prescriptive method is based on the use of tabulated data to determine the minimum thickness to withstand the effects of fire. The performance-based method comprises three components: fire modelling, thermal behaviour and structural behaviour.

The importance of compressive strength resides in the role masonry plays as a vertical loadbearing element subjected to predominantly compressive stresses. In addition, a clear understanding of the behaviour in the interaction of mortar-units under stress will result in a better comprehension of masonry. Walls are, in some cases required to resist horizontal forces and lateral pressure; therefore they should also be strong in shear and tension. Compressive strength is consequently of great importance in design. Multiple studies have determined that masonry's compressive strength is influenced by a specified number of parameters principally associated with mortar and unit properties, workmanship, and curing [15].

There is an evident reduction in compressive strength when subjected to heat; levels of variation with temperature need to be obtained to predict behaviour. Although in reality no work has been reported in this field, the aim of this chapter is to compile information describing general behaviour of heated masonry components.

Mechanical properties of structural members subjected to fire conditions are obtained from two regimens [16]:

-The steady state test is characterized by an initial heating phase without the application of load, and then the specimen is allowed to reach a specified temperature. Once the thermal equilibrium is achieved, the specimen is loaded at a uniform rate and stresses are recorded as a function of strain.

-The transient state test, where the load is applied prior to heat, maintained and recorded at a constant rate; meanwhile, the specimens are heated to a target temperature. The strain is constantly measured with high fire resistance devices and stress-strain relationships are obtained when the stresses are calculated from the loads.

Generally, higher strength is obtained from the steady state than the transient tests. Since for transient tests, the influence of the temperature is more severe on pre-loaded members [17].

Information presented here, highlights the importance of a better comprehension of the fire performance of lightweight concrete as the main component for blocks and therefore for masonry structures. The variation in some thermal and mechanical properties with temperatures is then presented. Reduced mortar properties are also included in this information; some mechanical, elastic and thermal and other relevant properties are shown. Finally general aspects of the effects of elevated temperatures on masonry walls are included.

2.2 Masonry unit properties at elevated temperatures

The quality of masonry depends on the quality of its constituents; the units are the most important component and should be of top quality. The word "*brick*" is usually referred to when discussing masonry units. However, masonry can also be made of blocks and stones (natural and manufactured); this appreciation is precipitated by the evident use and knowledge of bricks in old and historical masonry buildings.

The difference between bricks and blocks is mainly due to their sizes. The standard size for bricks is 337x225x112.5mm (L x w x t) and for blocks it is 440x215x100mm. The basic shapes are solid, cellular and hollow; developing hundreds of varieties when they are combined. Masonry units can be constituted of clay, concrete or calcium silicate. Concrete units can be divided into lightweight, dense and autoclaved aerated, whose difference is merely in density.

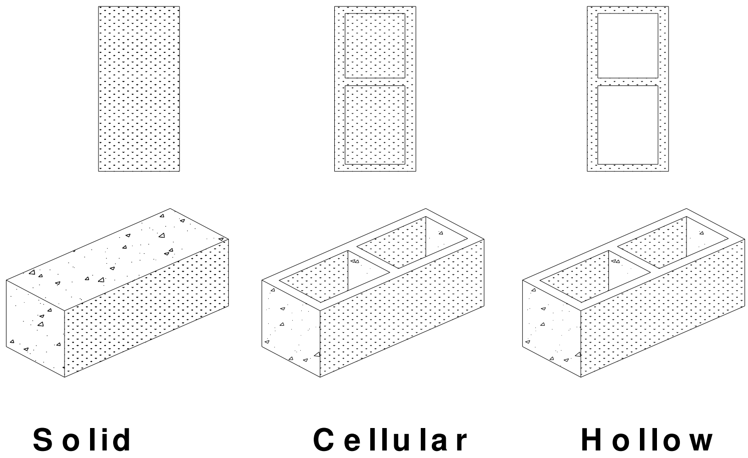


Figure **1:** Types of Blocks.

Lightweight aggregates can be classified as two types: natural (pumice, diatomite, volcanic cinders, etc) and artificial (perlite, expanded shale, clay, slate, sintered PFA, etc.).

2.2.1 Compressive strength

Lightweight concrete exhibits a reduction in strength when subjected to high temperatures but is normally less than that of normal concrete; this is mainly due to a combination of the excellent thermal properties of its aggregates and cement paste [7].

Abrams [18] conducted one of the first early studies on the effects of short-term heating of concrete to high temperatures. Cylinders made of expanded shale lightweight aggregates were tested. Concrete strengths ranged from 22.8 to 44.8MPa. Tests were not completed until the difference in temperature between four thermocouples was within 11ºC. Unstressed, stressed and unstressed residual tests revealed the excellent performance of lightweight concrete up to 480ºC, at which the strength retained was 75%, 90% and 53% respectively (see Figure 2). Higher variation in the compressive strength of stressed and unstressed tests at 93ºC and 204ºC was attributed to the presence of moisture despite of subjecting the specimens to heating preliminary periods of 3-4 hours.

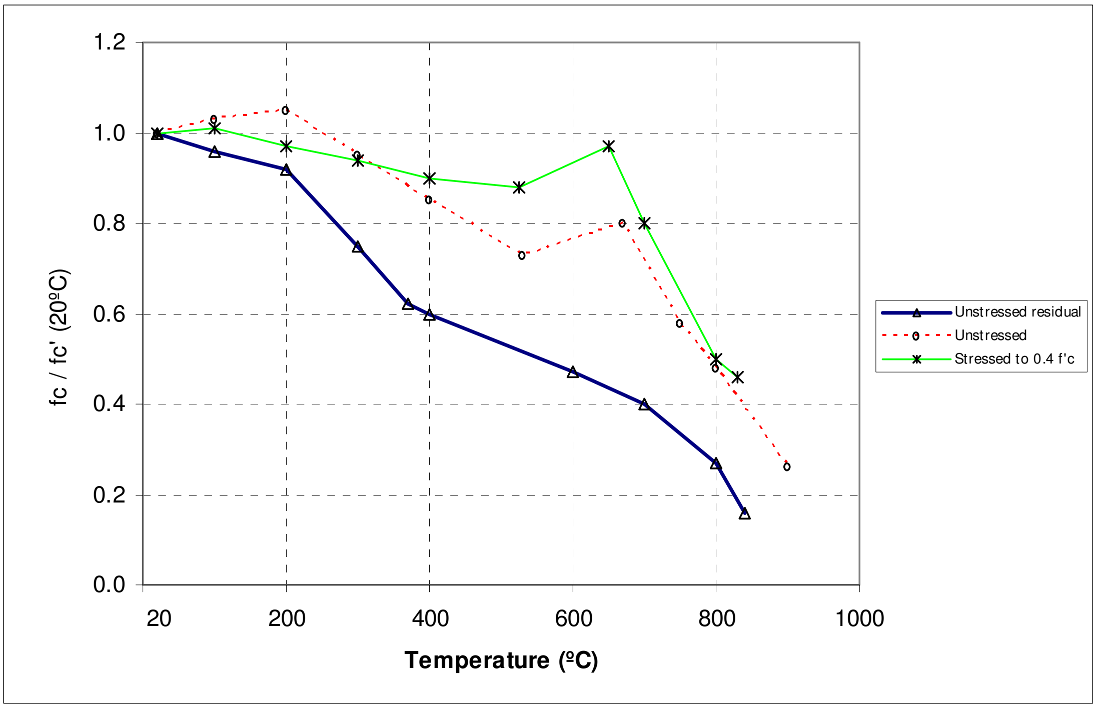


Figure 2: Reduce strength of lightweight concrete vs temperature [18].

Subsequent unstressed tests were carried out to study the behaviour of lightweight concrete in fire [19]. Two cylinders, with dimensions of 100 x 310mm and with a nominal strength of 69 MPa to 118 MPa were used. The specimens were tested at 90 and 150 days (see Figure 3) using a water/cement ratio of 0.36. The heating and loading rates were 2ºC/min and 0.8 MPa/s respectively. It was observed that the difference of strength loss with increasing temperature was insignificant. A typical "*breakpoint*" in the curve was observed at 300ºC; this was due to an explosive failure followed by the release of a lot of steam.

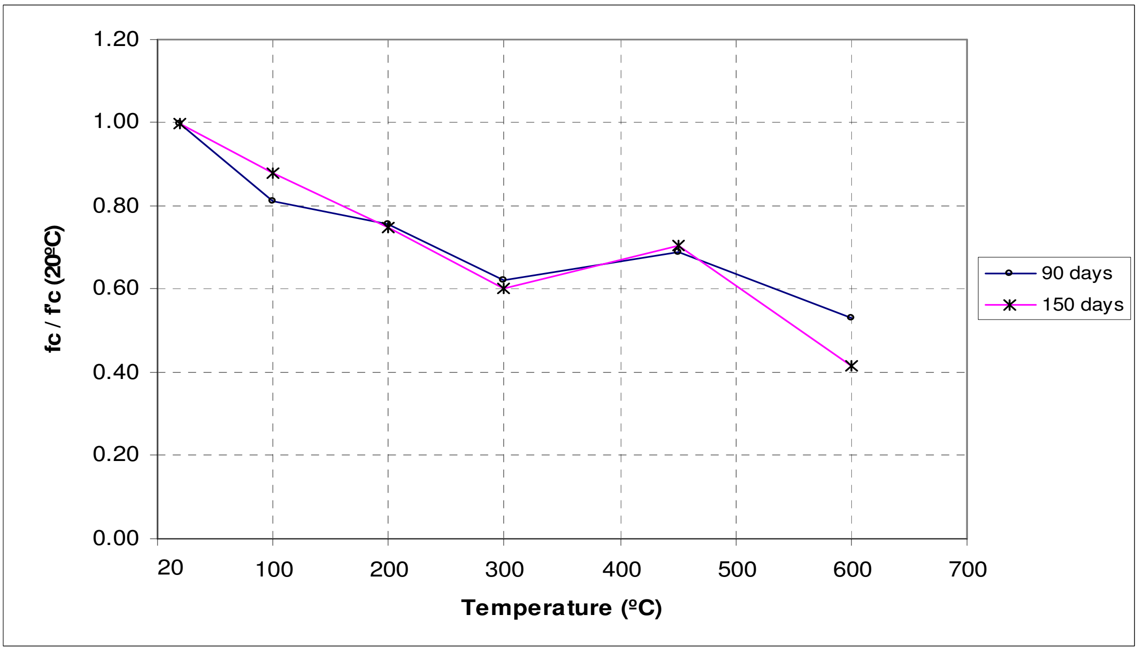


Figure 3: Compressive strength of 90 and 150 days lightweight concrete at high temperatures [19].

Although the graphic shows an apparent increase in the strength at around 450ºC, the strength was unexpectedly much reduced at 300ºC, for that reason explained before, that changed the tendency in both cases.

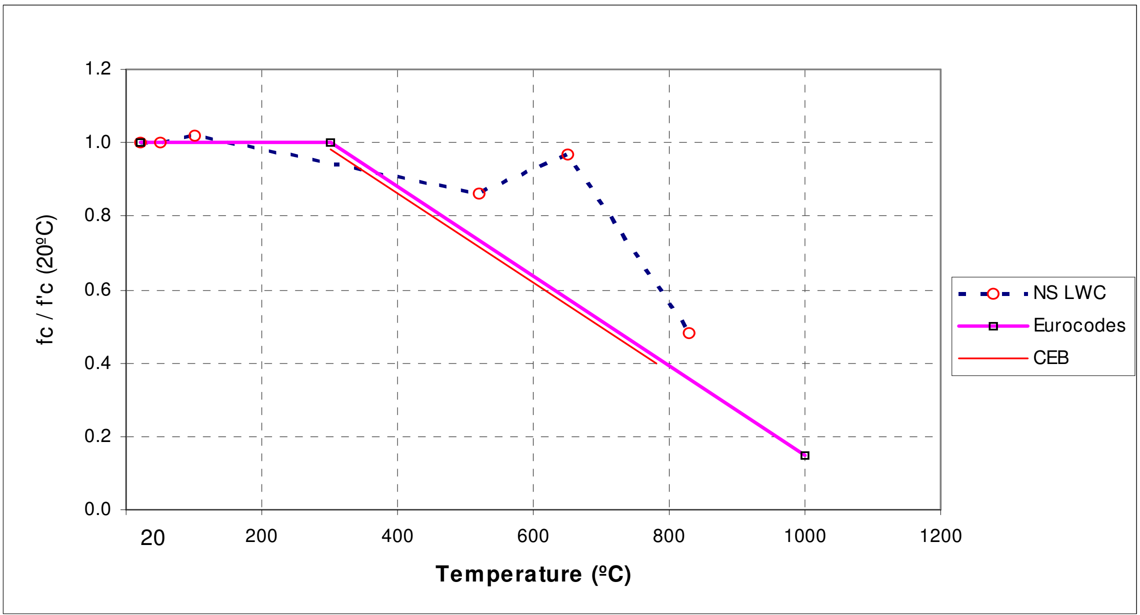


Figure 4: Comparison of design curves for compressive strength and results of stressed tests [20].

A fire test study on high-strength [HSC] and normal-strength [NSC] lightweight concretes against code data was conducted by Phan and Carino [20].

The specimens used in these studies had compressive strengths ranging from 20 to 150MPa. The heating rates varied from 0.2 to 32ºC/min, but the majority of tests used a heating rate of 1ºC/min. From Figure 4 it is observed that the Eurocode and Comites Euro-International Du Beton (CEB) provisions [21,22] were not conservative for normal strength lightweight concrete (NS LWC) for stressed tests.

From Figure 5 it can be observed that the compressive strength of HS lightweight concrete varies more unfavourably with temperature compared to NS lightweight concrete. This variation is more pronounced between 25ºC and 400ºC; meanwhile, this difference is less significant above 400ºC.

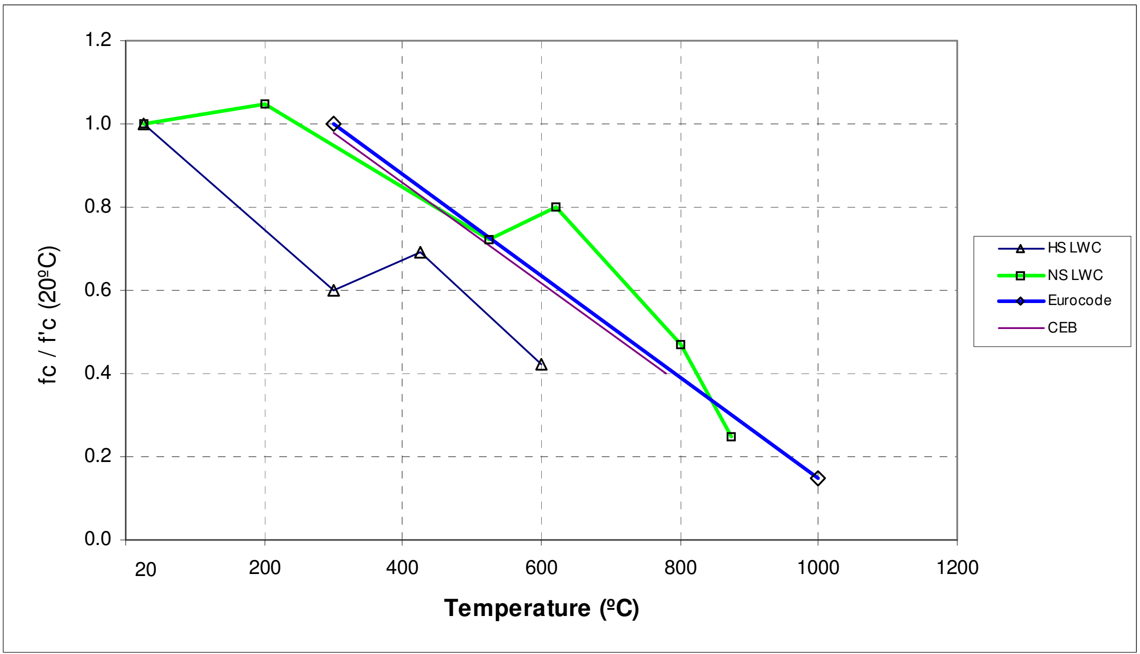


Figure 5: Comparison of design curves for compressive strength and results of unstressed tests [20].

The Eurocodes and CEB design curves are unconservative for both NS LWC and HS LWC in the temperature range between room temperature to about 350ºC. Above this temperature, the code design curves are more applicable to both NS and HS LWC.

For unstressed residual property tests, the Eurocodes and CEB design curves [21,22] are in a better agreement with HS LWC data at temperatures between 25ºC and 400ºC than that for unstressed tests (see Figure 6).

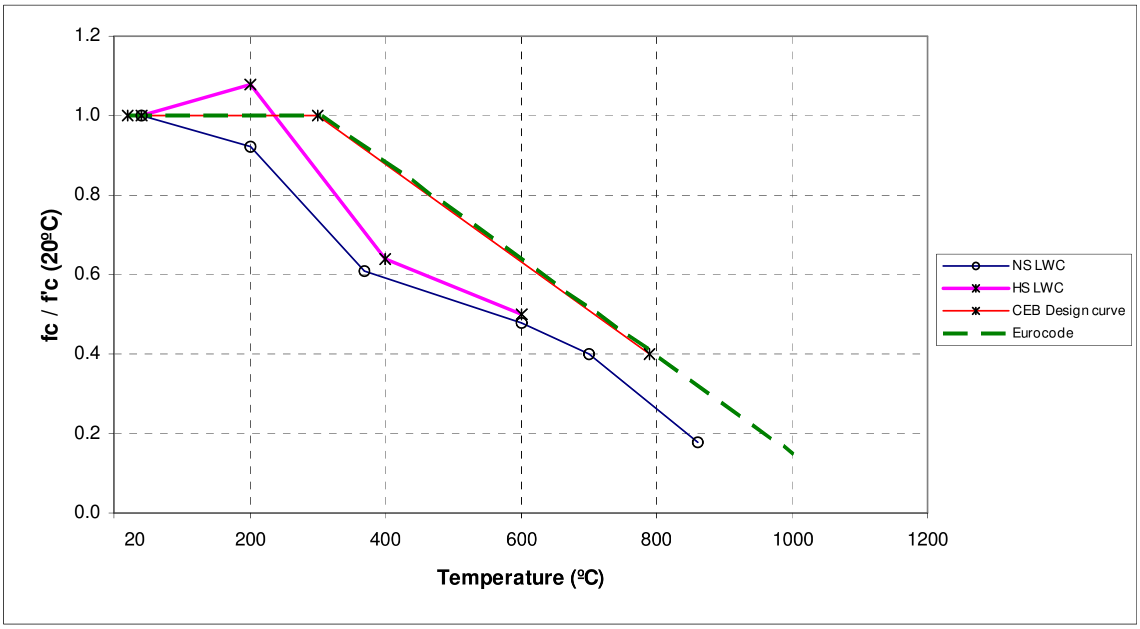


Figure 6: Compressive strength – temperature relationship for lightweight concrete using unstressed residual property tests [20].

Kodur and Harmathy [23] studied the reduced compressive strength of concrete using two different lightweight aggregates; one of them was incorporating natural sand. It was observed that the strength was almost the same up to about 200ºC in all mixes. Above 200ºC, the strength from the unstressed residual sanded mix test was the lowest, and stressed sanded mix reached the highest strength up to 800ºC (see Figure 7).

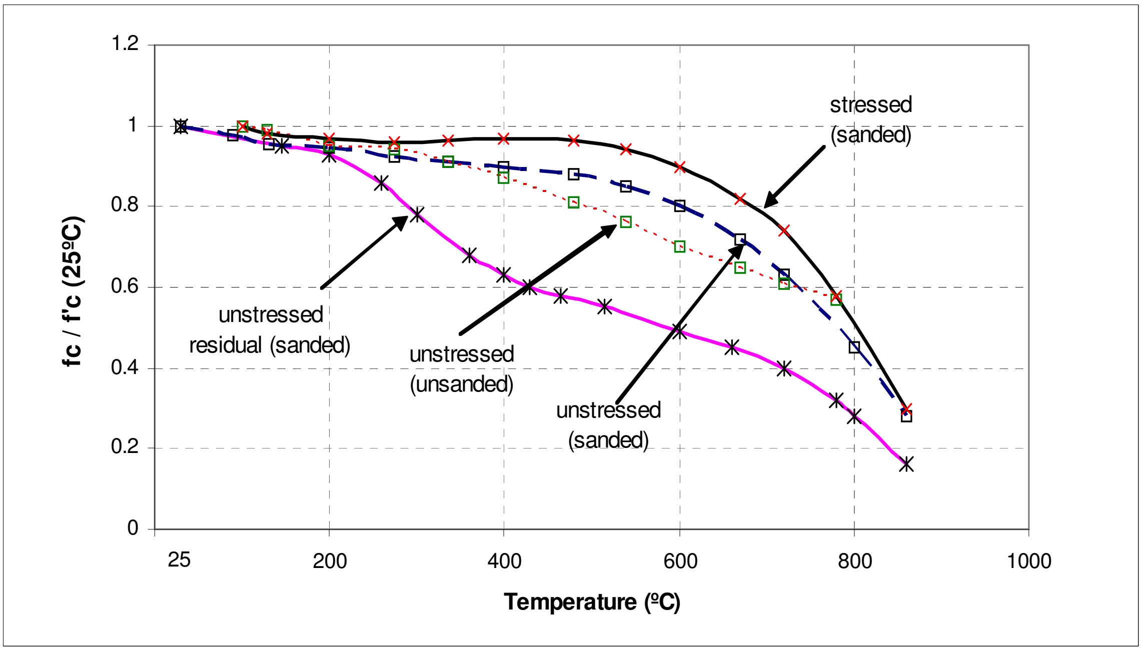


Figure 7: Reduction of the compressive strength of lightweight concrete at elevated temperature [23].

Structural lightweight concrete produced with pumice was investigated to obtain the compressive strength and weight loss after being exposed to high temperatures [24]. Silica fume (SF) was employed to substitute Portland cement in all mixes. Superplasticizers (SP) were added to half of the mixtures. The compressive strength was not affected by the increase of temperature up to 400ºC; these results were consistent with the conclusions obtained by other researchers [25,26] who found that the strength of lightweight concrete did not change significantly up to 500ºC. Figure 8 shows that after peaking at 100ºC the strengths decreased. The rate of decrease was very rapid between 400ºC and 800ºC. The higher resistance of lightweight concrete at 800ºC was explained by the effects of a lower coefficient of thermal expansion. The use of high amounts of silica fume produced a lower strength. All the mixes in the graph are indicated as "L-0-0", which means Lightweight concrete, percentage of pumice aggregate and percentage of superplasticizer.

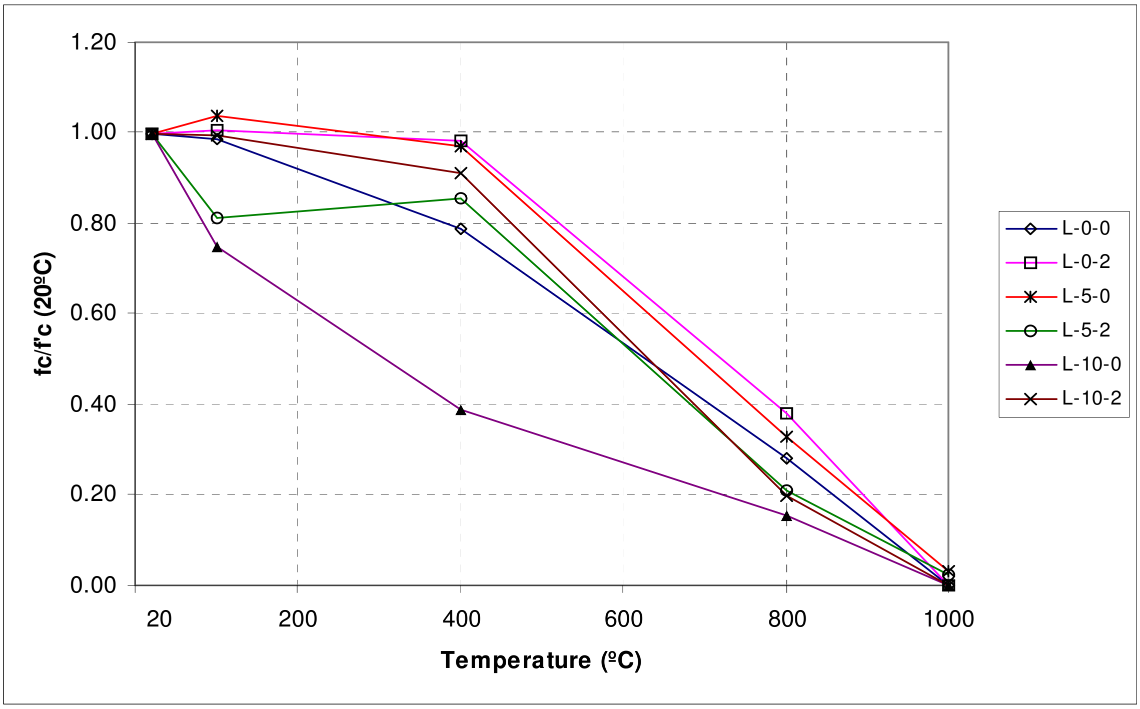


Figure 8: Strength of lightweight concrete at elevated temperature [24].

Tanyildizi [27] tested cubic specimens (100 mm x 100 mm x 100 mm) to generate the compressive strength of lightweight concrete, made of scoria aggregate and fly ash at elevated temperatures; they were heated up to 200ºC, 400ºC and 800ºC and maintained for 1 hour to achieve the thermal steady state. The heating rate used was 2.5ºC/min.

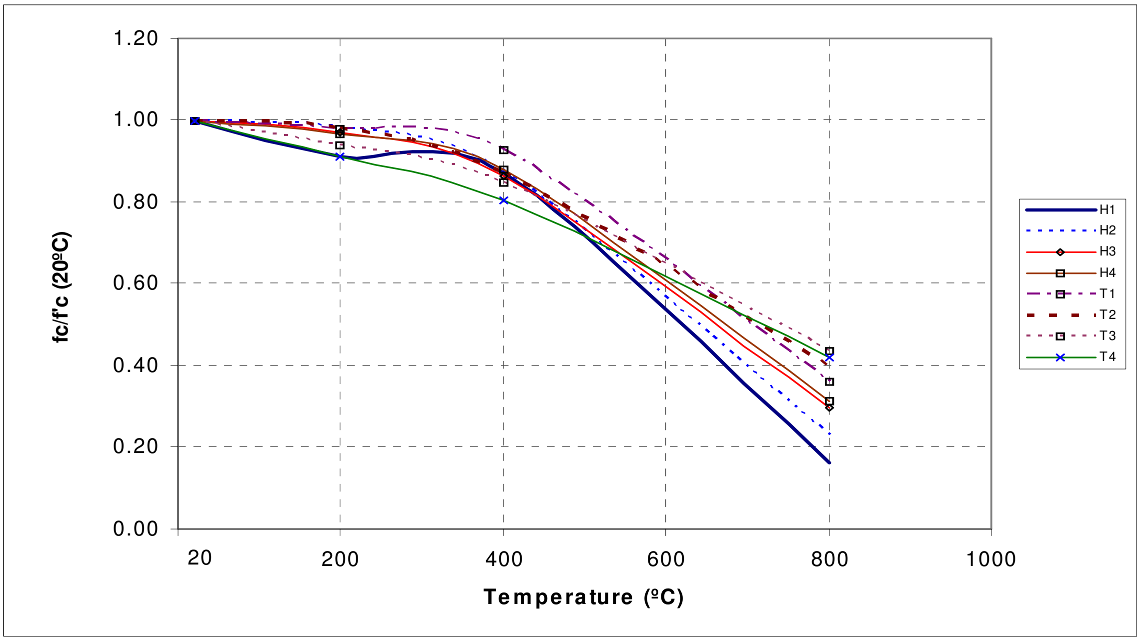


Figure 9: Reduced compressive strength of lightweight concrete at elevated temperature [27].

The results highlighted that each temperature range had a distinct pattern of strength loss. Figure 9 shows that the compressive strength suffered a minor decrease up to 400ºC. However, the strength dropped rapidly after this temperature.

2.2.2 Tensile strength

The tensile strength of concrete is important when considering cracking. For masonry assemblages loaded under uniaxial compression, cracking parallel to the line of action of the load implies some influence of the tensile strength of the masonry units. Depending on the load impact, tensile strength can be divided into flexural tensile strength, splitting tensile strength, and axial or direct tensile strength [28,29].

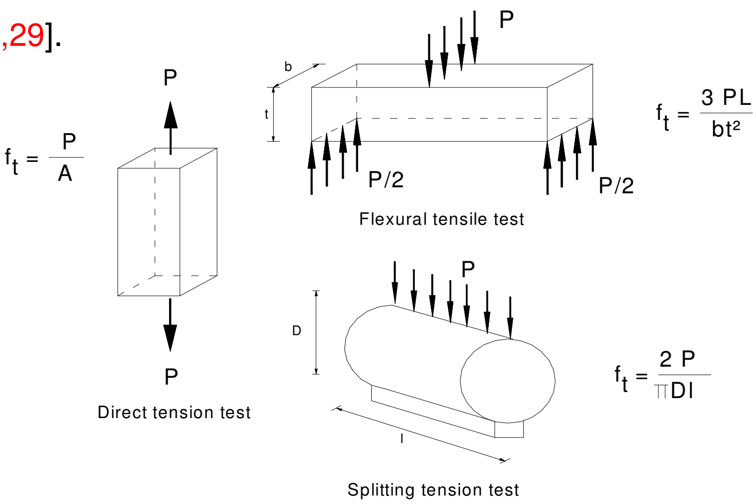


Figure 10: Types of tension tests [28,29].

The tensile strength of lightweight concrete is reduced when high temperatures are applied; this was demonstrated by Tanyildizi and Coskun [30], who tested three cylinders of 100 x 200mm made of mixtures containing fly ash. Reduced tensile strength presented in Figure 11 shows a slight reduction up to 400ºC then a sharp decrease was experienced after 400ºC. This change was assumed due to the formation of micro and macro cracks of the concrete during the heating phase. On the other hand, higher tensile strength was reached in those mixtures containing fly ash, owing to formation of tobermorite, which is known as a secondary product of hydration between lime and fly ash [31].

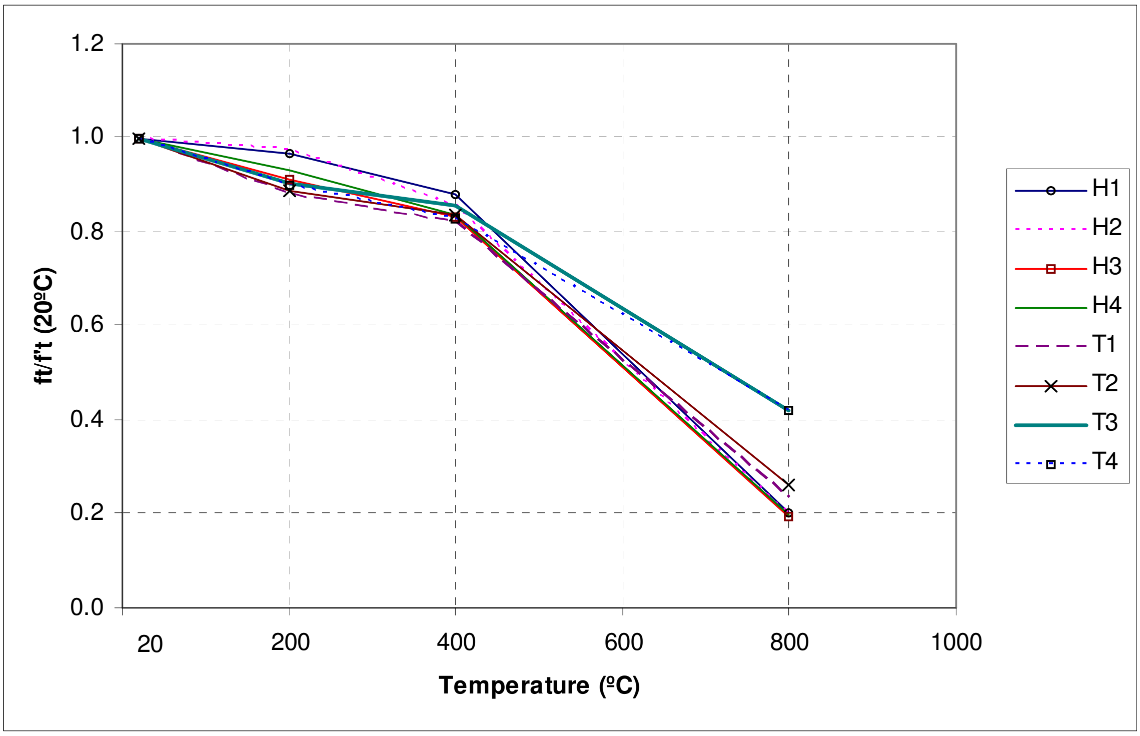


Figure 11: Splitting tensile strength of lightweight concrete at elevated temperature [30].

2.2.3 *Modulus of elasticity*

The modulus of elasticity is a property that defines the tendency of a material to be deformed elastically when a force is applied. Some studies have been conducted to define its behaviour at high temperatures.

Harmathy and Berndt [32] tested cylindrical specimens (1.9in x 3.8in) made of expanded shale aggregate concrete which were subjected to compressive loading in order to analyse the effects of elevated temperatures on the modulus of elasticity.

The specimens were cut by a diamond core drill from lightweight concrete blocks; three holes of 0.03inches were drilled in the samples to locate equal numbers of thermocouples for measuring the temperatures; three specimens were heated up to 1400ºF (760ºC) in 100ºF (38ºC) increments. The results of this study are contained in Figure 12; the residual modulus was maintained with minor variation up to 204ºF, subsequently an almost quasi-linear reduction was reached over 204ºF.

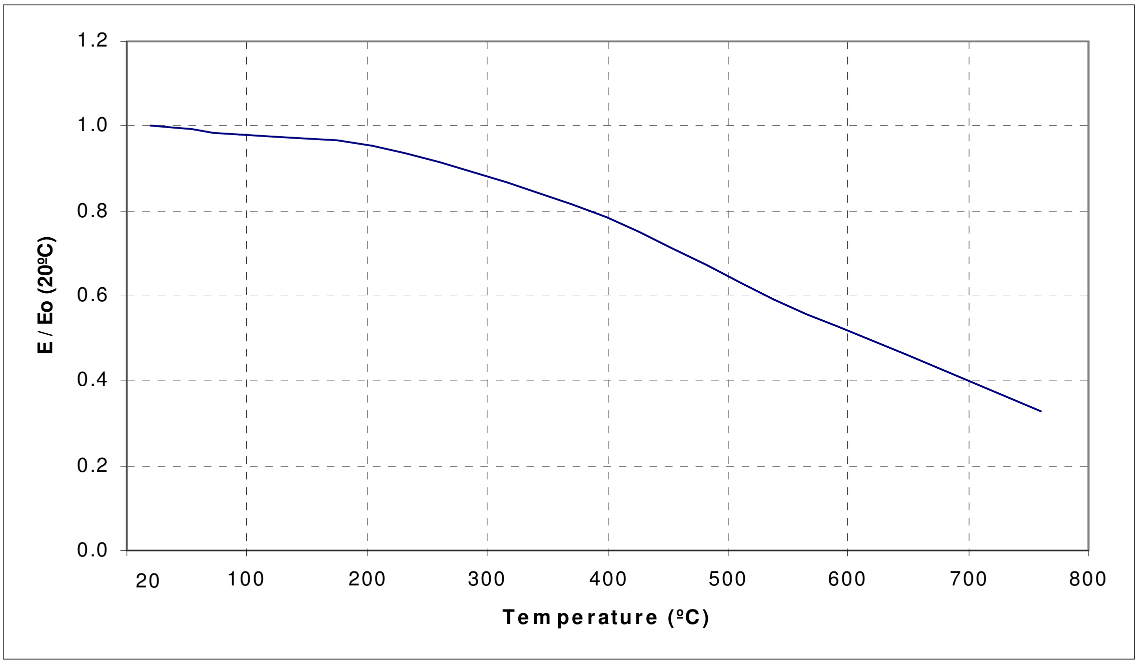


Figure 12: Modulus of elasticity in compression of expanded shale aggregate at elevated temperatures [32].

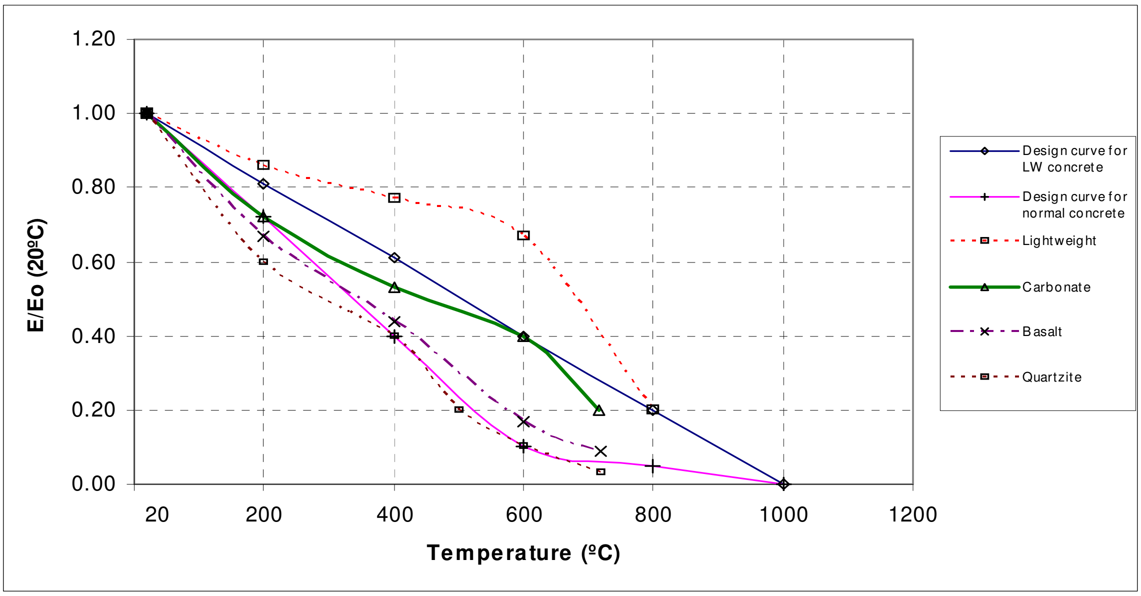


Figure 13: Modulus of elasticity of structural concrete with different types of aggregates [33].

Schneider [33] carried out a condensed survey on the field of concrete focusing on different properties at high temperatures. He studied the effects of heating concrete composed of different aggregates to determine their modulus of elasticity (see Figure 13).

He highlighted the importance of the water/cement ratio, type of aggregate, type of cement, aggregate/cement ratio, load level, heating rate, evaporation rate, age of concrete, type of curing and sealing, in obtaining the concrete modulus of elasticity at elevated temperatures. According to his results, lightweight concrete reached the highest residual modulus of elasticity, attributed to the excellent thermal properties of the aggregates.

Some values of modulus of elasticity for various types of aggregates with temperature are presented in Figure 14. All these aggregates experienced a rapid loss as the temperature increased. At 200ºC the modulus is reduced from 70% to 80%, at 400ºC values of 40% to 50% were reached. Bazant and Kaplan [34] associated this reduction with the breakage of bond in the microstructure of the cement paste when the temperatures increased and with the increase of rapid short-time creep.

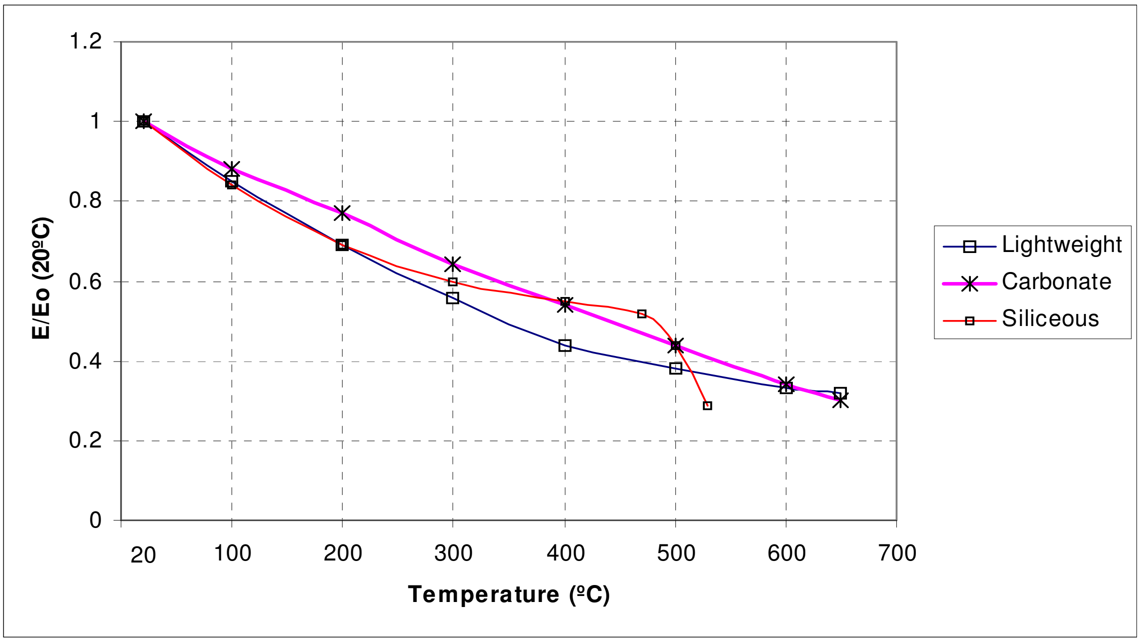


Figure 14: Reduction of the modulus of elasticity for various types of aggregates with temperature [34].

Hammer [26] demonstrated that the modulus of elasticity of lightweight concrete can decrease at a faster rate after 300ºC. Cylinders of 100mm x 310mm were cured at 90-150 days and heated to 100ºC, 200ºC, 300ºC, 450ºC and 600ºC, using heating and loading rates of 2ºC/min and 0.8 MPa/sec respectively. Two samples were tested for each temperature.

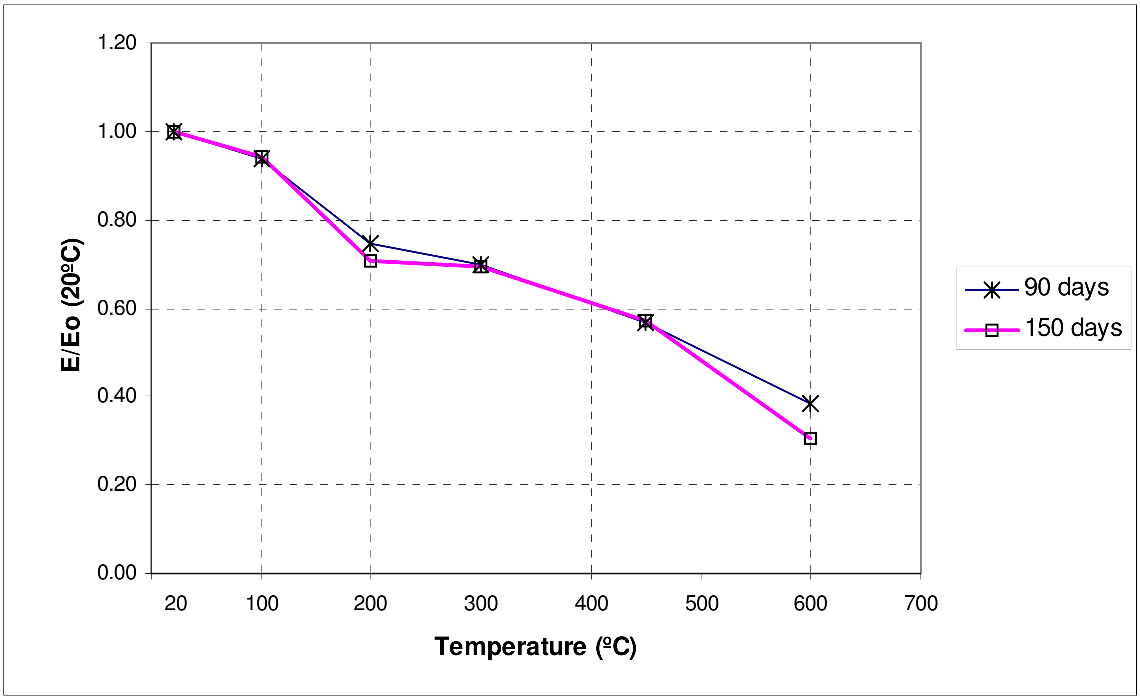


Figure 15: Elastic modulus of lightweight concrete at 90 and 150 days vs. temperature [26].

The elastic modulus from samples cured at 90 days was moderately less than that reached from concrete at 150 days (Figure 15). It is interesting to note that a "*breakpoint*" appeared at 200ºC, which differs from that obtained for compressive strength (see Figure 3).

The variation of elastic modulus with temperature from two types of high strength lightweight concretes was determined from unstressed and residual property tests [20]. From Figure 16 can be observed that both high-strength lightweight concretes had a significant reduction in elastic modulus between 100ºC and 200ºC.

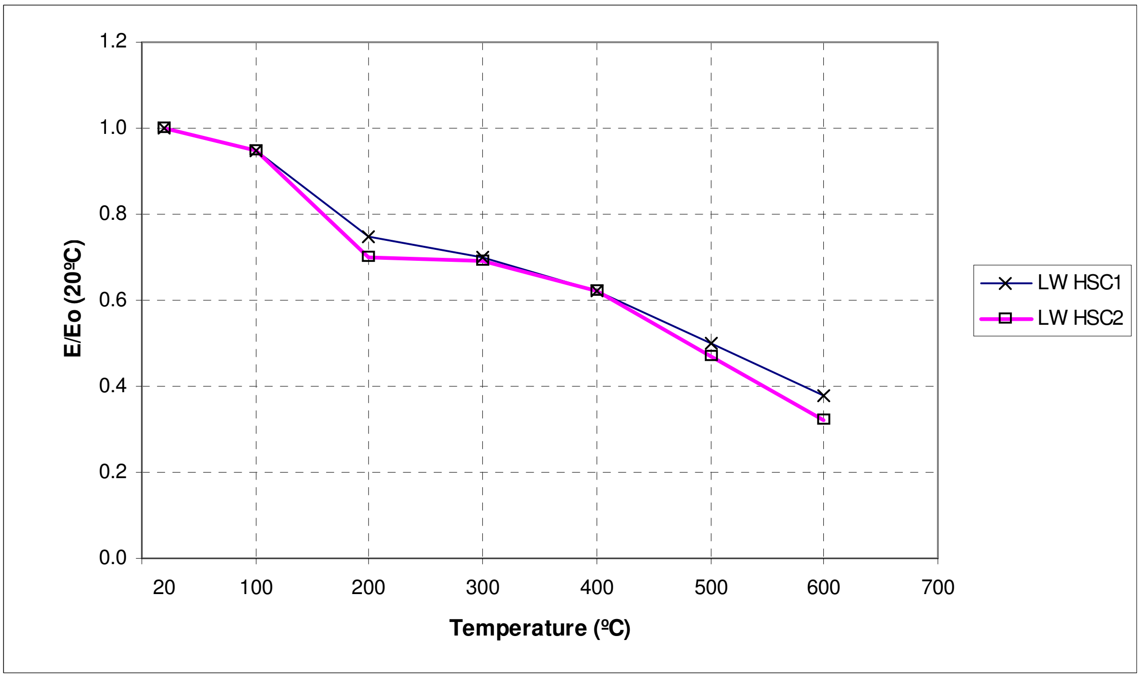


Figure 16: Elastic modulus - temperature relationship for Lightweight concrete obtained from unstressed tests [20].

In the case of unstressed residual property tests (Figure 17), this elastic modulus reduction was more pronounced at temperatures over 200ºC.

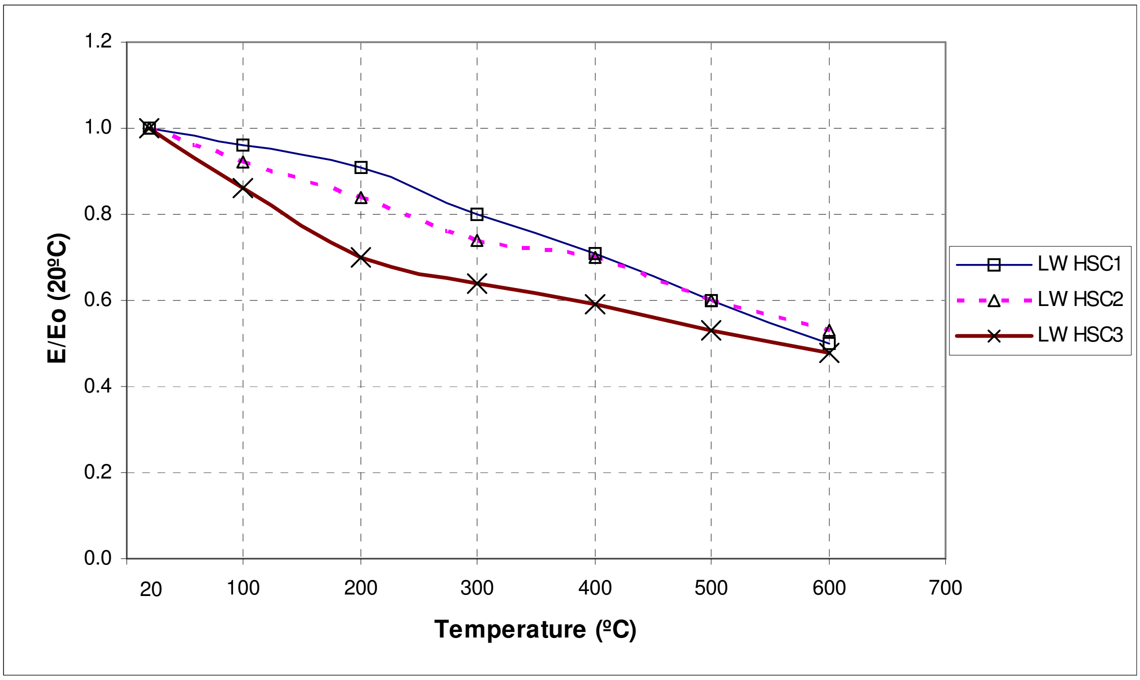


Figure 17: Elastic modulus - temperature relationship for Lightweight concrete obtained from unstressed residual property tests [20].

2.2.4 Poisson's ratio

Poisson's ratio was obtained from testing 3 cylinders of 6 x 12 inches at 70ºF, 250ºF and 500ºF. Cylinders were made of pelletized expanded slag aggregate, which were cured for 28 days and after were subjected to 50% of relative humidity at 70ºF for 100 days. The tests were based on compressive samples, final values being 0.15 for 70ºF and 250ºF; and 0.12 at 500ºF [35].

2.2.5 Moisture content

Attributed to high porosity, lightweight aggregates have a greater ability to absorb water; the initial strength of lightweight concrete can be significantly affected by this. Moisture content is also associated with the variation of thermal conductivity at high temperatures [33].

High moisture content will lead to increased pore pressure and temperature gradients during a fire. Sometimes lightweight concrete behaves worse than normal concrete in a fire because lightweight aggregates tend to work as reservoirs of evaporable water [36].

In general, moisture content is one of the main factors associated with concrete in the reduction of thermal resistance, thermal conductivity, strength, permeability, vapour pressure, etc [37,38]; it is also one of the most important causes of spalling [39], and is the main factor influencing the fire resistance of hardened concrete [40,41,42,43,44,45,46,47].

Thus, due to the high porosity level, the critical moisture content for lightweight concrete is still difficult to define. Malhotra [40] claims 7% by volume; however, other authors have accepted that a value lower than 7% is the critical moisture content for lightweight concrete [21]. More authors have declared that the moisture content inside the concrete will be higher than the moisture content near the concrete surface [39].

2.2.6 *Thermal expansion*

Thermal expansion of concrete is influenced by the type of aggregate especially due to its total volume. The coefficient of thermal expansion of lightweight concrete is dominated by the coefficient of the paste, due to its greater stiffness. Thermal expansion of concrete is divided into two parts: expansion of the cement paste and secondly swelling, which result from pressure due to the action of a temperature increase on water in capillary pores [48], although swelling does not occur in concrete in dry or fully saturated conditions. Minimum values of the thermal coefficient are found under these conditions.

A range of values for coefficients of thermal expansion for different lightweight aggregates are given at Table 2.1.

Table 2.1 Coefficient of thermal expansion of LWAC [49].

Type of aggregate	**Linear coefficient of thermal expansion (-22 to 52ºC) [10^{-6}/K]**
Pumice	9.4 to 10.8
Perlite	7.6 to 11.0
Vermiculite	8.3 to 14.2
Cinders	About 3.8
Expanded shale	6.5 to 8.1
Expanded slag	7.0 to 11.2

2.2.7 *Thermal conductivity*

The thermal conductivity is defined as the property of the materials to conduct heat. In general, lightweight concrete has lower thermal conductivity values than normal concrete attributed to the aggregate properties.

Thermal conductivity varies with increasing temperature due to the increment of porosity in the concrete as a result of the evaporation of pore water and dehydration of the cement paste. In a fire, these effects will produce pores in the surface of the concrete, resulting a heat insulating layer at the surface that will reduce the rate at which the concrete is heated [50].

Thermal conductivity of concrete depends on its unit weight and cement paste, but is also influenced by the moisture content and aggregate type [51]. This has caused new investigations to find the relationship between these factors. For instance, ACI 213 [52] suggests an increment of 5% of thermal conductivity for each 1% by weight increase in moisture.

In some countries like the UK and France this relationship is 11% for each 1%, in Germany it is a 6% [51] increase of thermal conductivity for each 1% of moisture content.

Thermal conductivity of lightweight concrete blocks with a maximum density of 1601 Kg/m³ may be calculated using the following formula [53]:

$$K = 0.5e^{0.02d} \tag{1}$$

Where

d is the density, lb/ft³

ACI 213 R-03 [54] suggests an equation to estimate thermal conductivity $(\lambda)$of structural lightweight concrete associating its dry unit weight (w):

$$\lambda = 0.0864e^{0.00125w} \tag{2}$$

Meanwhile, for moderate strength lightweight concrete the following equation is proposed:

$$\lambda = 0.023e^{0.002w} \tag{3}$$

The design thermal conductivity of lightweight concrete at high temperatures can be estimated by [22]:

$$\lambda_c = 1.0 - (\theta_c / 1600) \quad \text{for} \quad 20^\circ C \le \theta_c \le 800^\circ C \tag{4}$$

$$\lambda_c = 0.5 \quad \text{for} \quad \theta_c > 800^\circ C \tag{5}$$

Figure 18 shows the variation of thermal conductivity with temperature for lightweight concrete in accordance with BS EN 1994-1-2 [22].

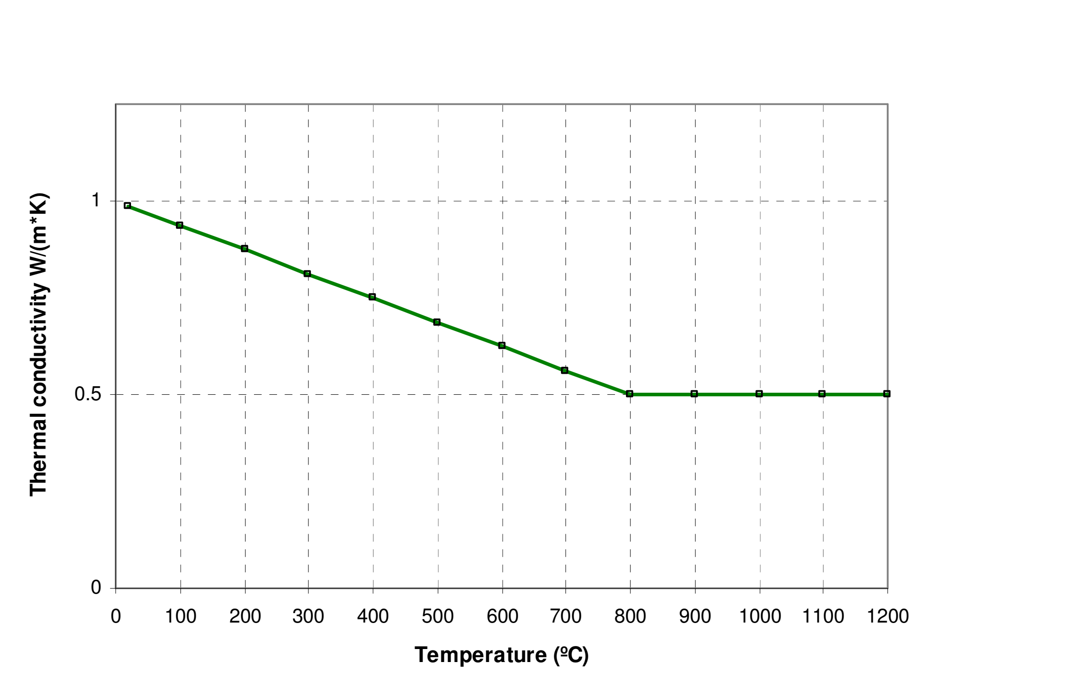


Figure 18: Thermal conductivity of lightweight concrete at high temperatures [22].

2.2.8 Emissivity

This property measures the efficiency of a material when one of its surfaces emits energy relative to a black body. A material with an emissivity value of 0 would be considered a perfect thermal mirror [55]. The emissivity values for concrete are not clearly defined; ETI [55] suggests 0.92, EN 1992-1-2 [56] considers 0.7 as the value for concrete, and Incropera and DeWitt [57] recommend values between 0.88 and 0.93.

2.2.9 Specific heat

Specific heat is the measure of the heat energy needed to raise the temperature of a unit quantity of a material by a certain temperature interval. Data for specific heat on lightweight concrete is very limited; however, some values show that they are very similar to those for normal concrete.

Lo-Shu et al [58] established a density of lightweight aggregate concrete of 800-1900Kg/m³ for specific heat values of 0.19-0.20Kcal/KgºC; these authors argued that the moisture content of concrete has a considerable effect on the specific heat. Van Geem [59] obtained a specific value of 960J/Kg·K for lightweight concrete with expanded shale aggregates.

In the case of fire the heat capacity of the aggregates will control the heat capacity of the concrete. Those concretes with a high heat capacity will permit a smaller temperature increment than those with a lower heat capacity for the same fire exposure conditions [49]. Chadderton [60] gives a specific heat value of 1000J/Kg·K for lightweight concrete with a density of 600Kg/m³. The specific heat of lightweight concrete according to EN 1994-1-2 [22] can be taken as 840J/Kg·K and can be considered independent of the temperature in the concrete.

2.3 Mortar properties at elevated temperatures

Mortar is the component to bond units in masonry structures; it should be able to withstand constant conditions of loads, weather, etc, but it can also serve many functions such as:

-transmitting pressures through the individual units

-maintaining the sound insulation of a wall through the reduction of greater pores, for which sound can be transmitted.

-maintaining the thermal characteristics of a wall, it is well known that heat gain or loss is dependant on openings, which are minimized by the mortar joints.

-filling the joints between the units and therefore increasing the resistance to moisture penetration, etc.

The risk of mortar to be exposed to high temperatures is increasing constantly. However, the actual research on this is extremely limited and more investigations need to be carried out in order to have a better understanding of its behaviour in fire.

The majority of previous investigations [6,61,62] have been carried out with the incorporation of additives as a solution to increase mortar strength. Material and environmental aspects are reported as the principal factors to define the behaviour of mortar at elevated temperatures. Material factors include the type of aggregates, aggregate-cement paste bond, thermal compatibility between components of the mixture and properties of cement paste. Whereas heating rate, duration of the exposure at maximum temperature, cooling rate, loading conditions, and moisture regime are considered as environmental factors [6].

Mortar, to be exposed in fire, should comply with requirements given at EN 1996-1-1 [63]; which specifies three types: general purpose, lightweight and thin layer.

2.3.1 Compressive strength

The importance of determining the mortar compressive strength is due to its direct influence on the compressive strength of masonry, but has also been taken as a measure of quality control. Mortar strength increases as cement content is raised, but decreases as lime content is maximized.

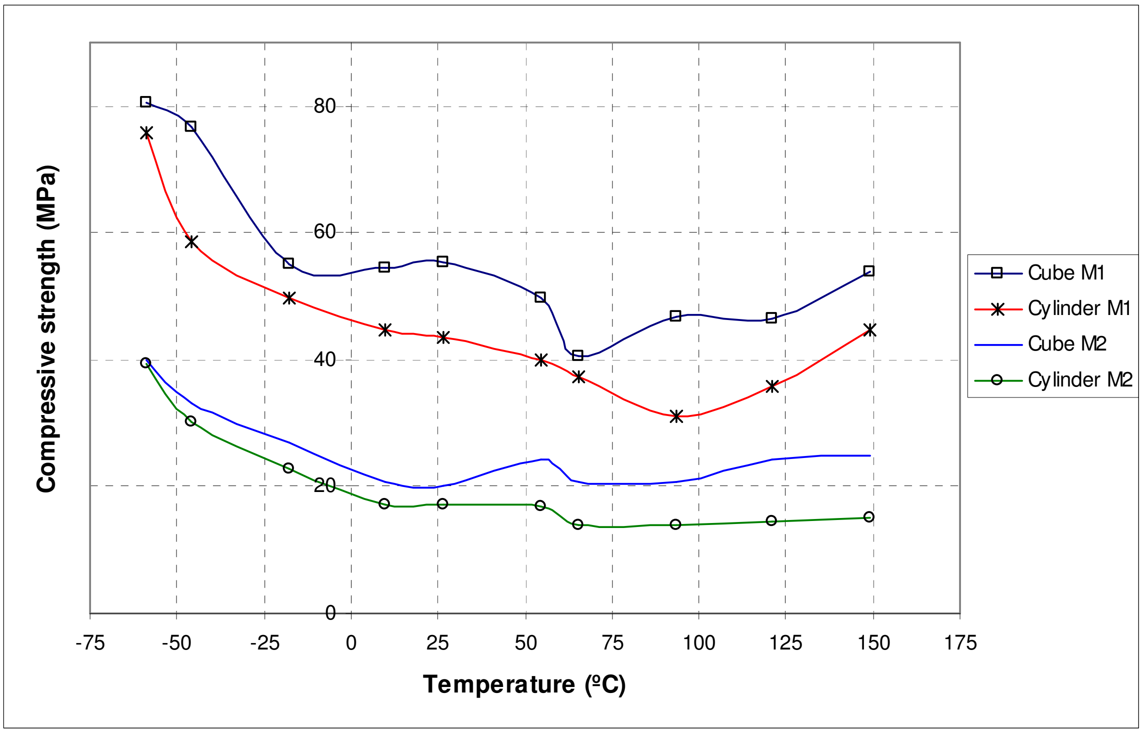


Figure 19: Variation of compressive strength of mortar with temperature [64].

During the 1950's some investigations were conducted into studying the variation of two types of mortars (1:2 and 1:4.5 proportion by weight and denoted as M1 and M2) between the range of -60ºC to 150ºC [64]. Three mortar cubes and cylinders were subjected to a preconditioning treatment between -57ºC and 149ºC for 24 hours. The results are presented in Figure 19. It can be observed that at -57ºC the strength increased more than 60% and 100% for mix M1 and M2 in comparison with that at room temperature. Meanwhile, at 232ºC, M1 and M2 strengths were reduced by 30 and 60 percent from the strength obtained at ambient temperature.

Gnanakrishnan and Lawther [2] reported that mortar can suffer a considerable strength loss at about 800ºC; as a consequence of this, the topmost units will rotate and horizontal cracks (due to tensile forces) in the topmost mortar layer will appear.

High strength mortar in fire was studied by Cülfik and Özturan [6]. Mortar cylinders were made according to ASTM C39 [65], one mix containing 5% of graphite powder and another mix without it. The specimens were subjected to 300ºC, 600ºC and 900ºC applying heating rates between 2 and 8ºC/min, and a cooling rate of 0.4ºC/min. They were also maintained at the maximum temperature for 1 hour and 10 hours.

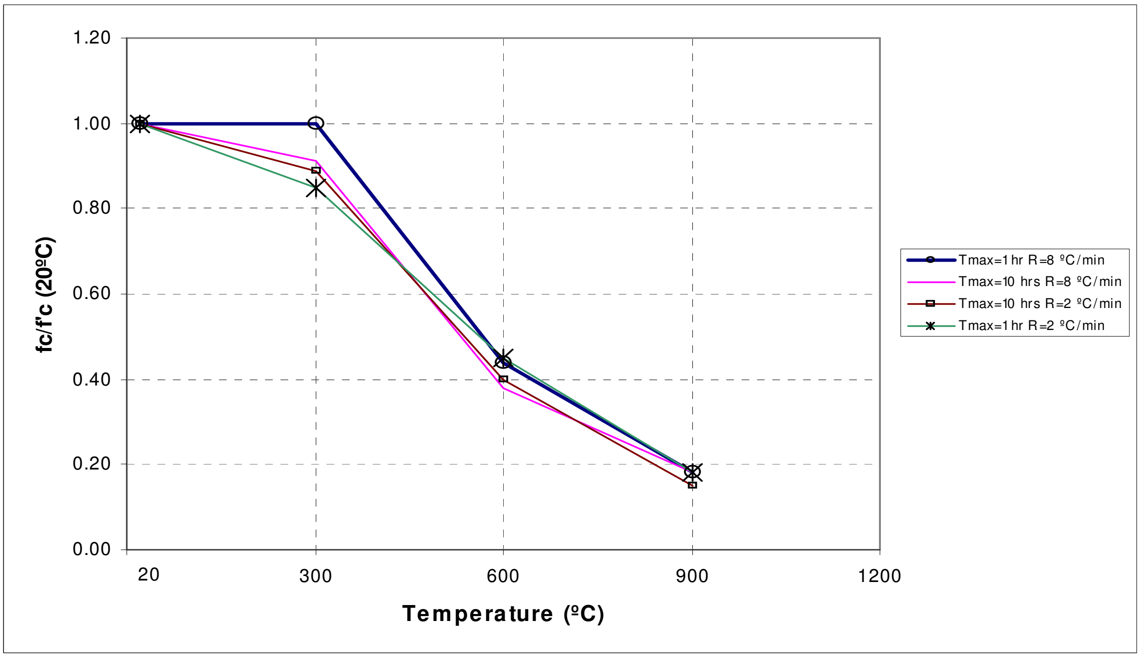


Figure 20: Reduced compressive strength of high strength mortar [6].

In general, a greater loss in strength was reached in the ordinary mix (see Figure 20). This difference was attributed to the excellent thermal properties of the graphite powder, which enhanced the decrease of compressive strength by reducing the amount of microcracks in the specimens; authors emphasized that microcracks were caused due to the differences in thermal properties of the sand particles and the cement paste.

Recent studies have demonstrated the existence of three zones that define the variation of mortar properties with temperature [61]. In the first at about 300ºC, the mechanical properties are the same or better than those at room temperature. The second or intermediate zone, between 300ºC and 600ºC, is characterized by a moderate reduction of the properties; finally in the high zone, over 600ºC, a rapid drop of the properties is registered. Further experimental investigations were conducted to evaluate the compressive strength of mortar correlating with those zones. Ordinary mortar and one mix incorporating silica fume were tested. In general, the compressive strength of the mortar within silica fume was maintained greater than that made of ordinary mortar (see Figure 21). The loss of strength was originated by dehydration, vapour pressure, and destruction of the products of hydration especially in the interfaces of aggregate/cement paste.

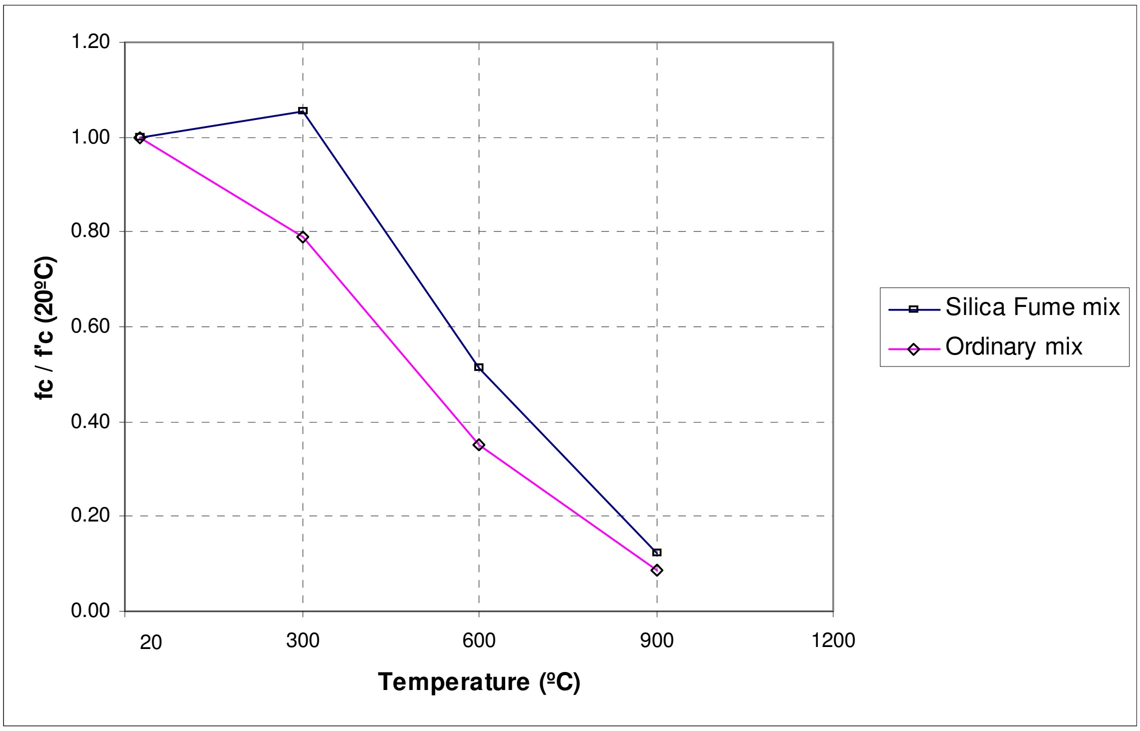


Figure 21: Compressive strength of mortar vs. heating temperatures [61].

These investigations also highlighted the level of porosity in all the specimens which was much more voluminous at temperatures over 600ºC.

It was demonstrated that the compressive strengths of normal and high strength mortar at elevated temperatures can be improved by the inclusion of polypropylene fibers [62]. The compressive strength of four mixtures (Normal strength [NS], high strength [HS], high strength with 1% of steel fibre [HFFS] and high strength with polypropylene fibre [HSSF]) was determined up to 900ºC. It can be seen from Figure 22 that the reduced strength of all mixtures increased approximately 12%-69% at 300ºC. These increments were attributed to the release of pressure by drying, but also to the formation of tobermorite formed by the reaction between the unhydrated blast furnace slag particles and lime. Normal (NH) and High Strength (HSS) mortars did not exhibit a strength loss up to 600ºC, this was attributed due to the minor content of hydroxide in the cement. In general, the strength was higher for the water cured mortars than autoclave cured ones (ac) due to the minor amount of lime and unhydrated blast furnace slag in the last mortars. It is also assumed that the effect of the polypropylene fibers increased the strength of the water cured mortars. It is also observed that due to explosive disintegration, the compressive strength of some mixtures was not obtained above 300ºC.

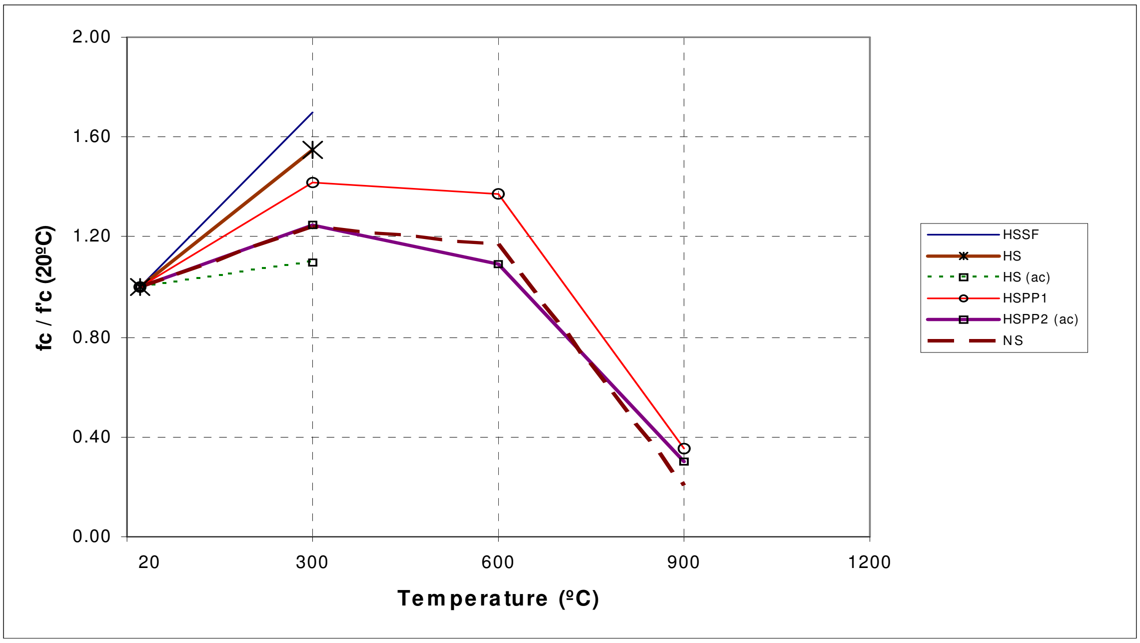


Figure 22: Reduced compressive strength of high strength mortar at elevated temperatures [62].

The findings were that mixtures containing large amounts of calcium hydroxide can cause a decrease in the compressive strength at temperatures over 300ºC owing to increased microcracking around the calcium hydroxide crystals. It was also explained that decomposition of calcium hydroxide in lime and water vapour at 350ºC may cause severe damage because of lime expansion during the cooling period. Finally when the temperature was increased up to 900ºC the residual strength dropped to around 30% in all the mixtures.

2.3.2 *Tensile strength*

The tensile strength of mortar experiences variation when temperature is increasing. As with the concrete, there is still no widely used test method to determine the mortar tensile strength under fire conditions. However, many direct and indirect procedures have been applied.

The variation of the tensile strength in two types of mortars at high temperatures was investigated by Saemann and Washa [64]. Three mortar briquettes for each mix were tested between the range of -60ºC and 150ºC. The investigations revealed that as the temperature decreased below room temperature the tensile strength increased (30%), but tensile strength was reduced to the lowest values at 66ºC (see Figure 23) where the strength was decreased by approximately 40% and 20% for mix M1 and M2 respectively than that at room temperature.

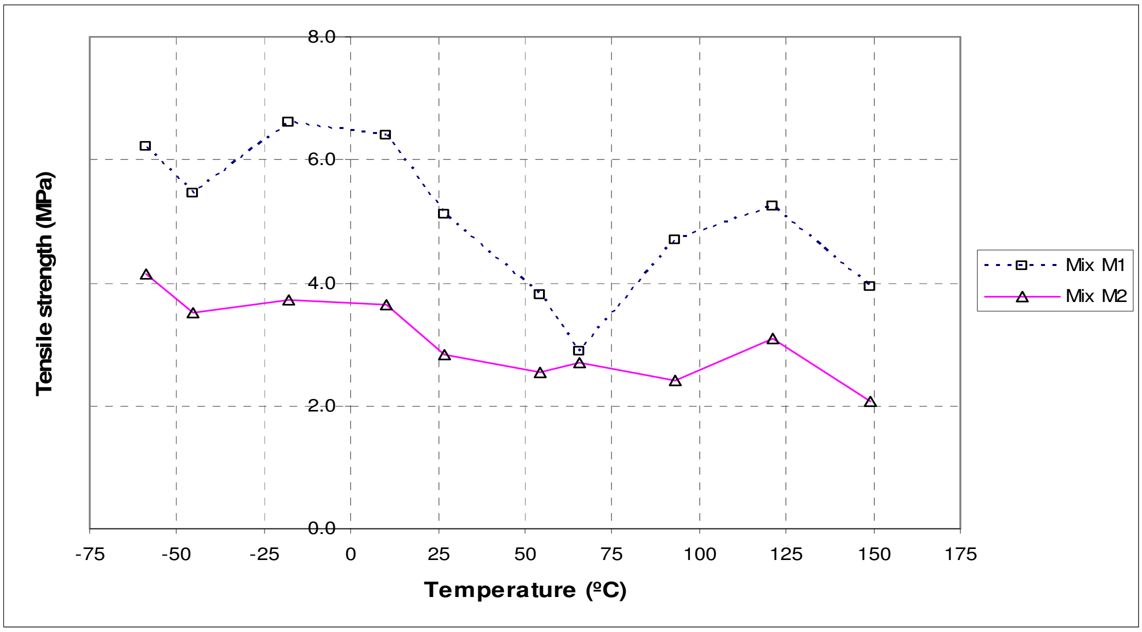


Figure 23: Variation of mortar tensile strength at high temperatures [64].

The diminution of the tensile strength was evaluated from two mortars, incorporating silica fume in one mix. Mortar was made of 1:3 (cement:sand) proportion, using two water/cement ratios of 0.5 and 0.3. Prisms of 4 x 4 x 16cm were cast and cured to the age of 80 days and exposed to temperatures up to 900ºC [61]. In general, the loss of tensile strength for both mixes seems to be regular or as quasi-linear (see Figure 24).

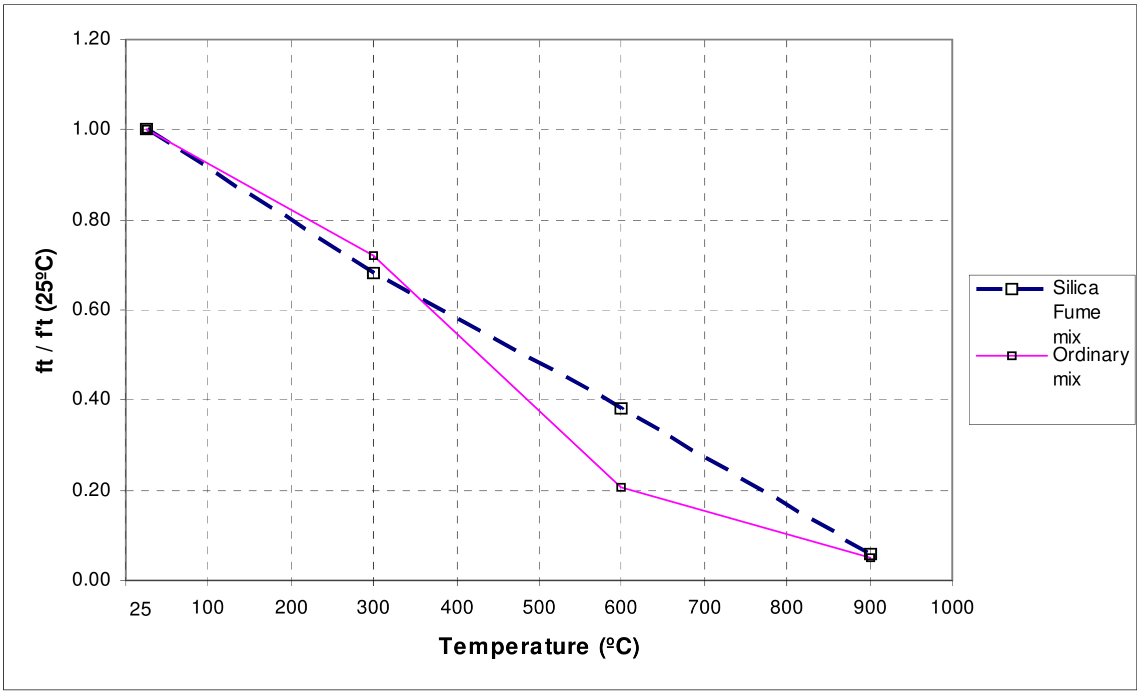


Figure 24: Reduced tensile strength of mortar vs. temperatures [61].

2.3.3 Modulus of elasticity

The mortar modulus of elasticity shows a significant reduction at elevated temperatures. Saemann and Washa [64] investigated the variation of the secant modulus of elasticity in mortar at temperatures ranging from -60ºC to 150ºC, for which three mortar cylinders were capped using cement paste. The modulus of elasticity was determined at a 1/3 of the ultimate load. Figure 25 illustrates the change of modulus of elasticity with temperature. It can be observed that at -60ºC the modulus was about 20% higher than that at room temperature for M1 and 50% for M2; at 150ºC the modulus was reduced to about 20% in comparison with the strength at room temperature.

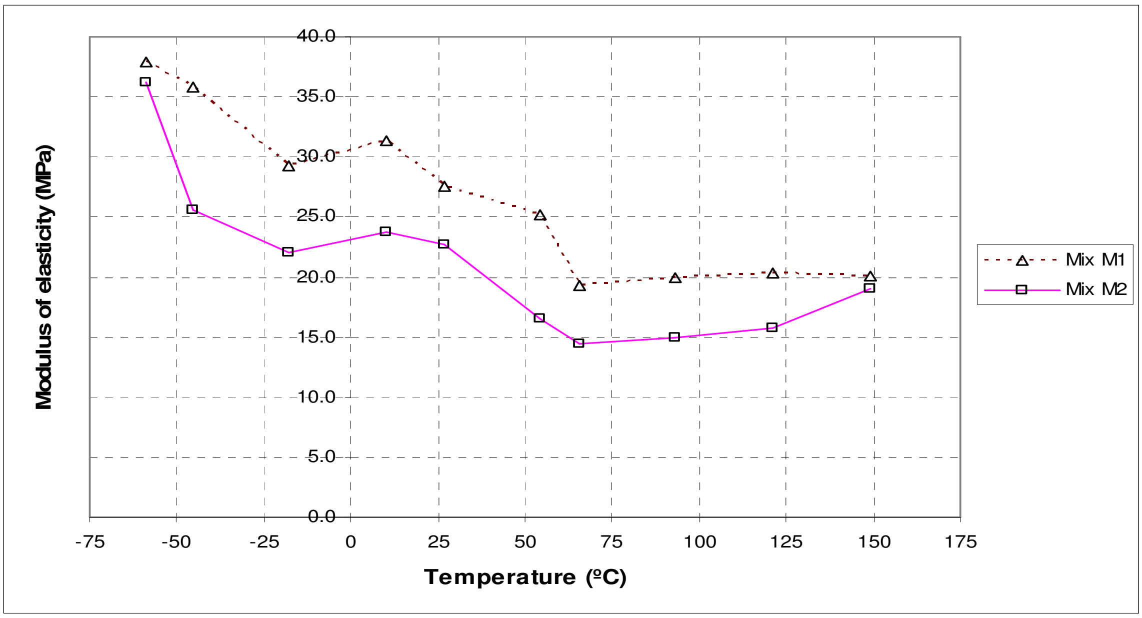


Figure 25: Modulus of elasticity of mortar vs. temperatures [64].

Recent studies on the residual static modulus with temperature have shown a quasi-linear behaviour [6]. The reduced elastic modulus of an ordinary mortar and another mix containing graphite powder is presented in Figures 26 and 27. It is observed that for the ordinary mortar, the residual elastic modulus retained about 67% in comparison with 97% reached by the graphite powder mortar at 300ºC. But this reduction was around 90%-88% of the initial modulus of elasticity for the ordinary mix at 600ºC; meanwhile, for the graphite powder mortar the reduction was 80%-88%.

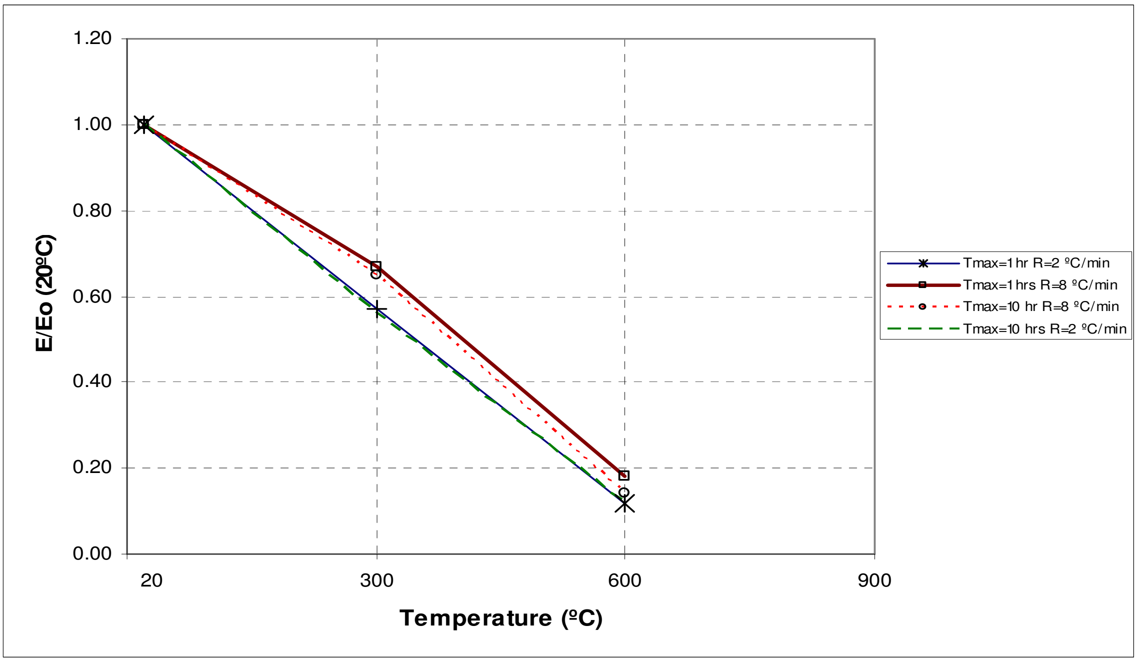


Figure 26: Reduced modulus of elasticity of ordinary mortar vs. temperatures [6]

Additionally when specimens were heated to 900ºC, the strength was so reduced that it was impossible to accurately measure the static modulus of elasticity, in fact, this loss was larger than that in the specimens tested for compressive strength.

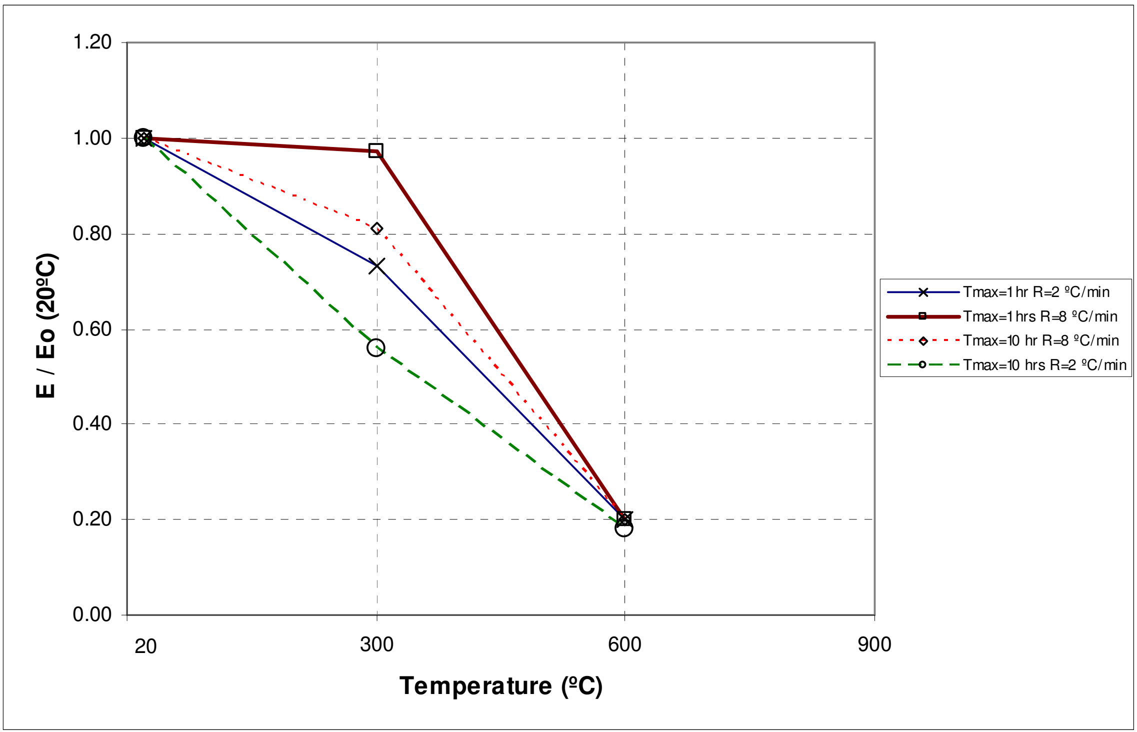


Figure 27: Modulus of elasticity of graphite powder mortar vs. temperatures [6].

Aydin et al [62] conducted some experimental investigations to determine the effects of elevated temperatures on the elastic modulus from water and autoclave cured mortars. The authors reported a general higher deterioration on the modulus of elasticity than the compressive strength from the same mix at equal thermal conditions. All mortars had a reduction in the modulus of elasticity at 300ºC. However, it was interesting to note that the compressive strength did not exhibit a significant reduction but the modulus of elasticity had a reduction of about 34%-40% at 600ºC. Finally the modulus was around 20% at 900ºC (see Figure 28).

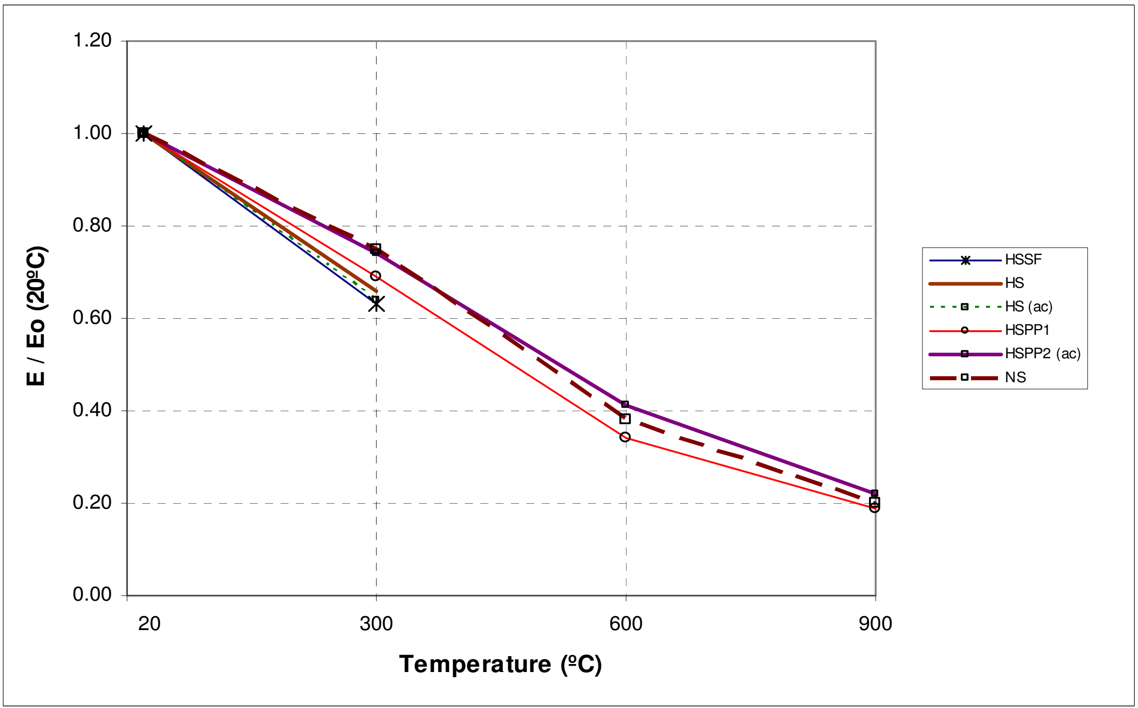


Figure 28: Reduced modulus of elasticity of mortar vs. temperatures [62].

2.3.4 Moisture content

The strength of mortar is affected by the moisture content at high temperatures; this was confirmed from investigations carried out on portions of broken mortar cubes [64]. All samples were placed in a gas oven at 104ºC until equilibrium was reached.

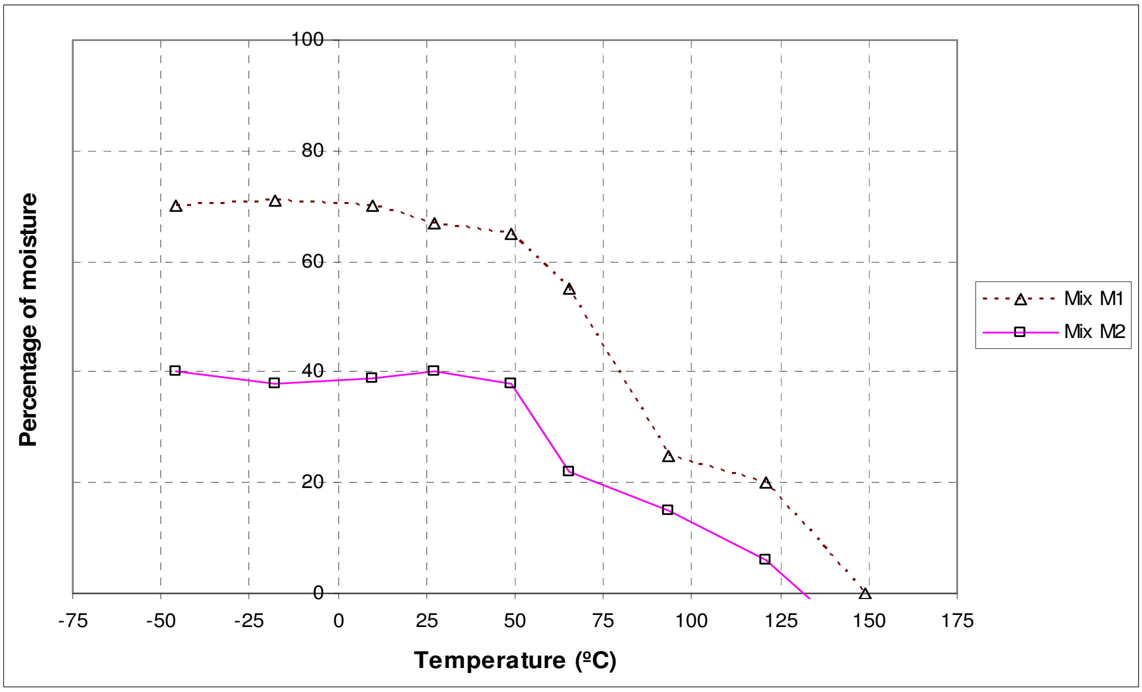


Figure 29: Moisture content of mortar at high temperatures [64].

Results in Figure 29 illustrate a permanent level of moisture at the range of -57ºC to 49ºC, which was significantly reduced at 49ºC-66ºC; the small positive values at 93ºC to 121ºC indicate the presence of moisture despite the 24 hrs temperature preconditioning.

2.3.5 Thermal conductivity

Thermal conductivity of a cement mortar was measured from specimens subjected to four types of conditions:

1) Specimens at room temperature not exposed to any load (denoted by NL)
2) Specimens exposed to a gradual temperature increase up to 800ºC during 2 hours and then left for another 2 hours at 800ºC, but without previous mechanical load (TL)
3) Specimens exposed to a mechanical load of 90% of compressive strength but without thermal load (ML)
4) Specimens exposed first to a mechanical load of 90% of compressive strength, then to a gradual temperature increase up to 800ºC over 2 hours and finally left for a further 2 hours at 800ºC (MTL)

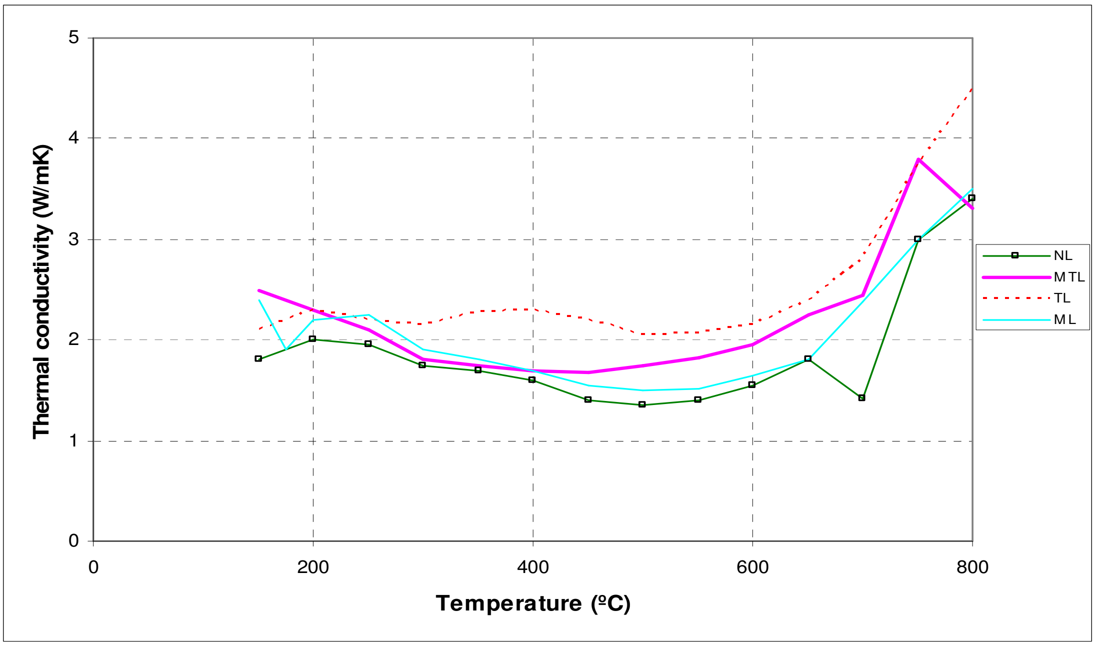


Figure 30: Thermal conductivity of mortar at high temperatures [66].

Three test specimens of 71x71x71mm were tested for each condition. TL samples reached maximum values of thermal conductivity at 800ºC; MTL samples achieved values of 10%-30% lower that that in the previous samples. Finally NL samples exhibited the lowest conductivity values (see Figure 30). Conclusions revealed the significant influence of thermal and mechanical loads affecting the thermal conductivity in that temperature range [66].

2.3.6 Emissivity

The emissivity of a material has two variables: the roughness and the surface deposit, which may be the oxide underlying element, dust, oil or paint [67]. Emissivity values for lime-mortar fluctuate between 0.90 and 0.92 at 38ºC-260ºC [68], meanwhile cement-mortar emissivity value is 0.86 [69].

2.3.7 Specific heat

A cement mortar was tested to obtain its specific heat capacity at elevated temperatures [70,71,72]. Mortar specimens of 71x71x71mm were cast using a proportion 1:3 (cement:sand) with a water/cement ratio of 2; they were subjected to 800ºC. The specific heat had a constant increment especially in the range of 25ºC-600ºC; this was attributed to the effects of the aggregate properties. At 25ºC the specific heat was 730J/(Kg·K), meanwhile, it was 1125J(Kg/K) at 575ºC (see Figure 31).

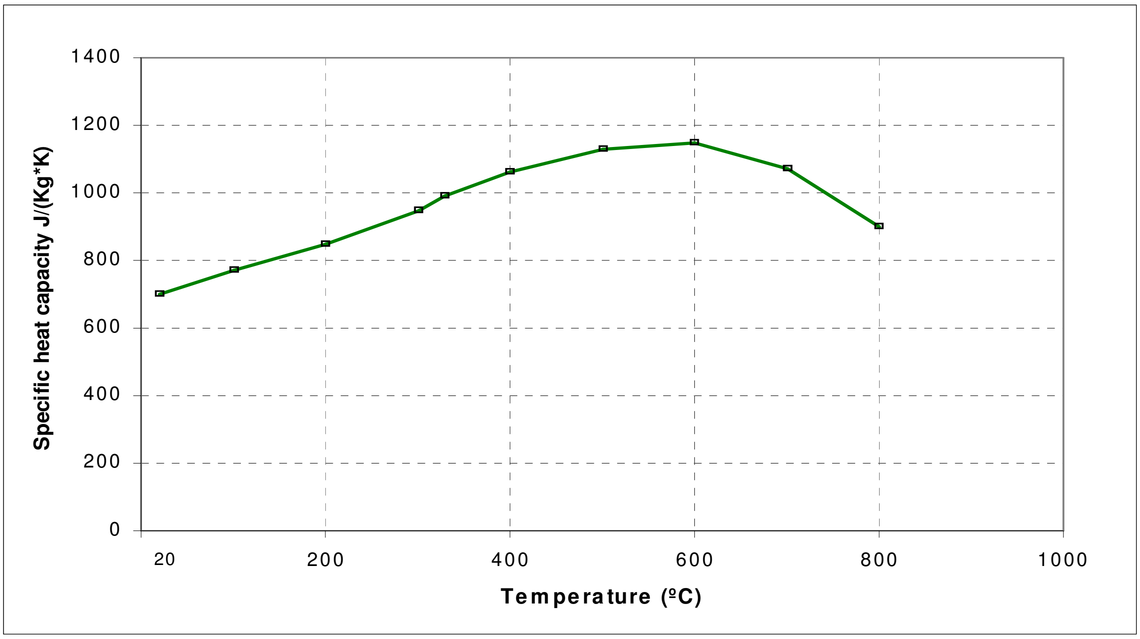


Figure 31: Specific heat of mortar at high temperatures [72].

2.3.8 *Effects of cooling condition on the residual strength of mortar exposed to high temperatures*

Calcium hydroxide contained in hydrated Portland cement plays a predominant role on the residual strength of mortar and concretes subjected to elevated temperatures when cooling down slowly or rapidly. Removing its contained water at 400ºC-500ºC will leave calcium oxide (lime), but once moist air is absorbed it will rehydrate causing an expansion in the volume of the mortar. This explains cases in which heat damaged concretes are immersed in water and experience a significant increase in strength.

If the specimen is cooled down slowly, reformation of the calcium hydroxide will have more time to take place and the mortar reaches its maximum damage level after the cooling. If the cooling is faster, the reformation of calcium hydroxide will take place at a slower rate after the fire and then the concrete will reach its minimum strength some days after the fire. The speed of this reformation depends on the moisture content of the air and size of the structure.

Research was devoted by Shoaib et al [73] to investigate the effects of slag mortars subjected to high temperature and then cooled down slowly and rapidly. Mortar was made of two slags: air-cooled and water quenched, and were compared against a mortar made with sand; three water-cement ratios were used: 0.4, 0.5 and 0.6. All mortars were immersed in water for 90 days and then cured at laboratory temperature for near by 4 months. Mortar specimens were exposed to 600ºC for two hours. Three cooling methods were used: water, air and furnace cooling.

It was observed that irrespective of the cooling method, all mixes suffered a reduction in the compressive strength. Results in Figure 32 present a substantial reduction of strength, which was 53%, 53% and 58% for the sand mixes cooled in water with water/cement ratios of 0.4, 0.5 and 0.6 respectively.

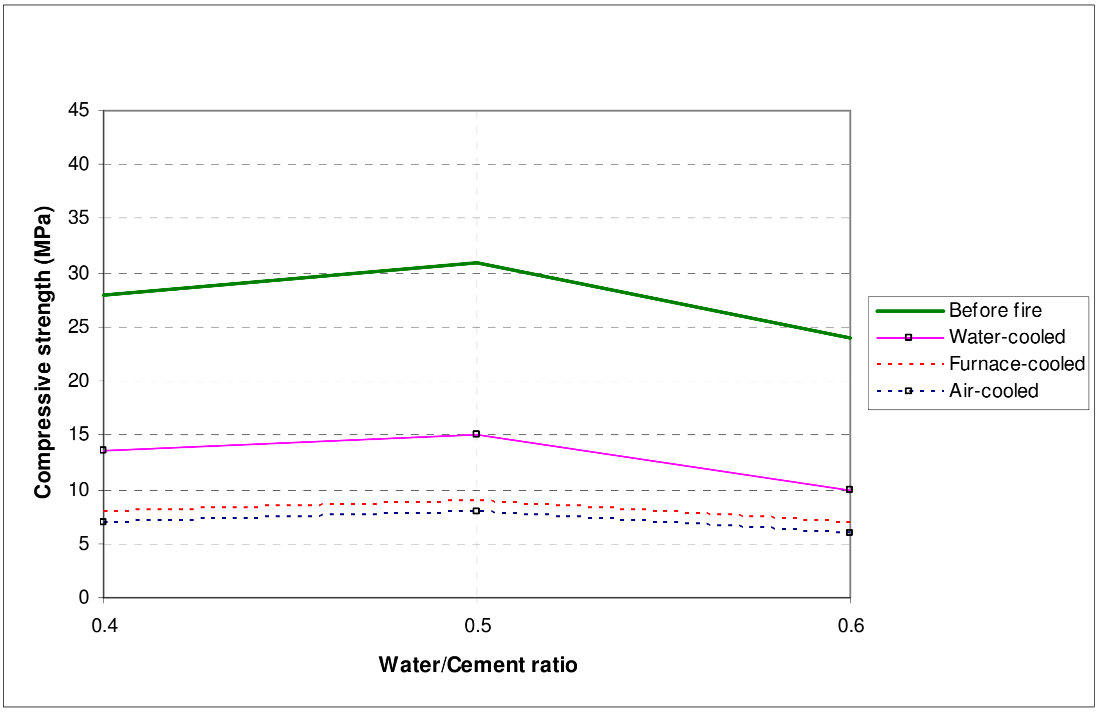


Figure 32: Compressive strength vs w/c ratio for sand mixes at age of 7 months [73].

This variation was approximately 59%, 53% and 71% for air-cooled mixes with water/cement ratios of 0.4, 0.5 and 0.6 respectively (see Figure 33). Finally in the case of water-quenched mortar the strength was 77%, 83% and 66% for the same water/cement ratio than previous (Figure 34).

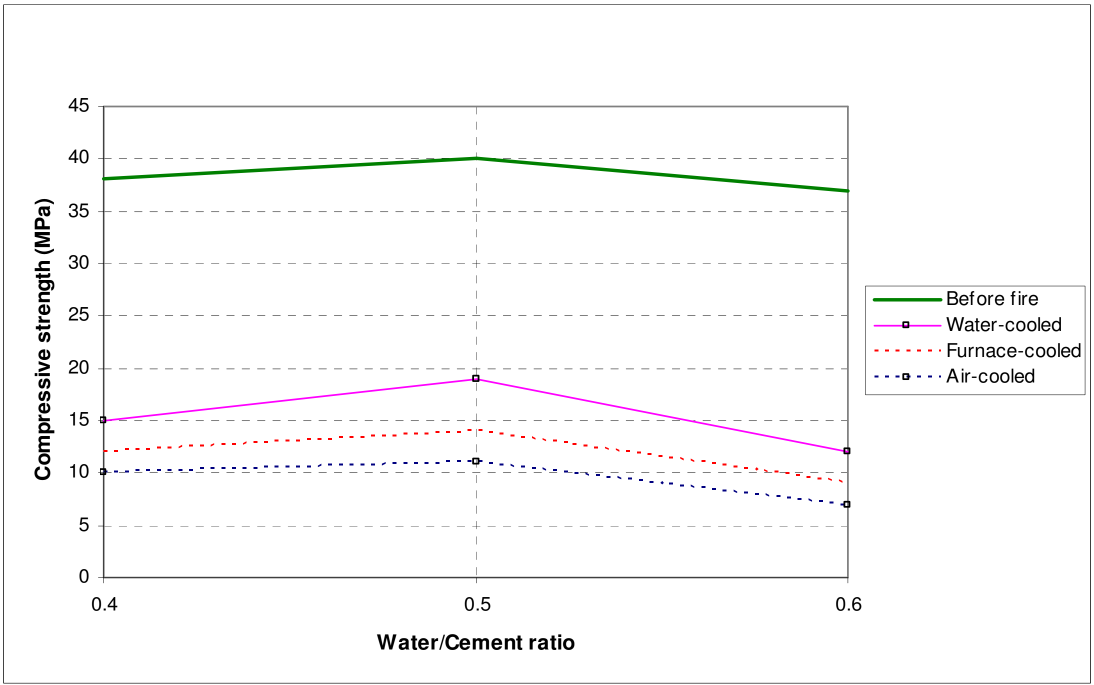


Figure 33: Compressive strength versus w/c ratio for air-cooled mixes at age of 7 months [73].

The reduction of the strength was provoked by decomposition of some components: the thermal expansion causing a change in volume, the thermal stresses in the matrix during cooling, and the method of cooling. Cooling in air was the method in which the compressive strength was the most reduced.

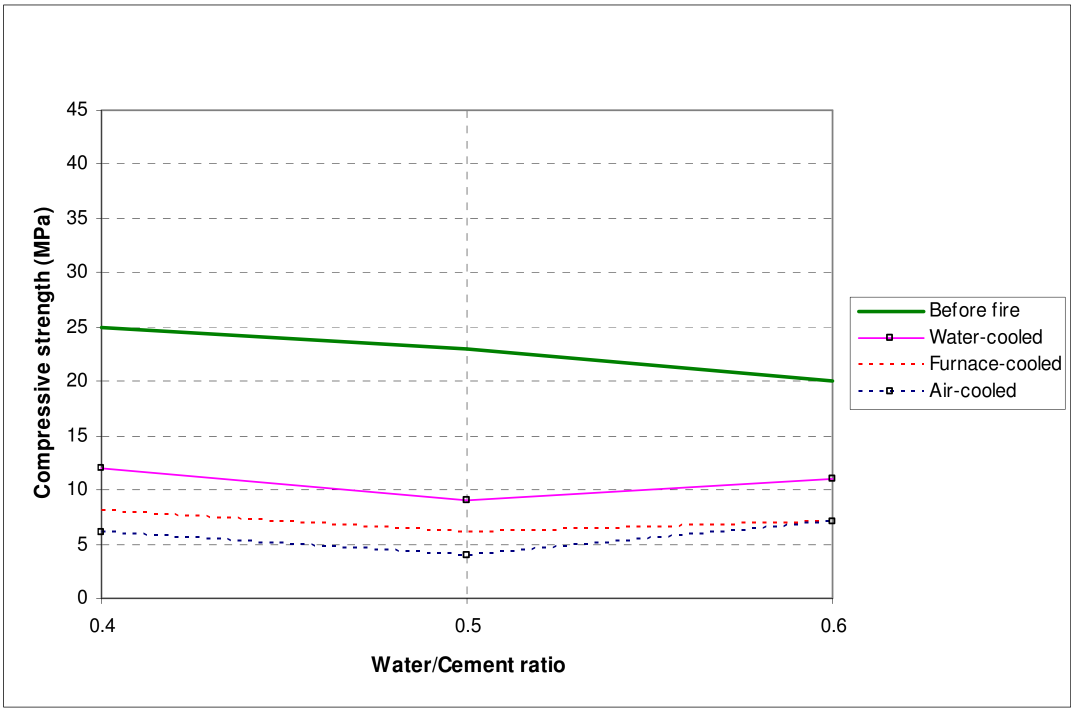


Figure 34: Compressive strength versus w/c ratio for water-quenched mixes at age of 7 months [73].

2.4 Effects of fire on different aspects of masonry

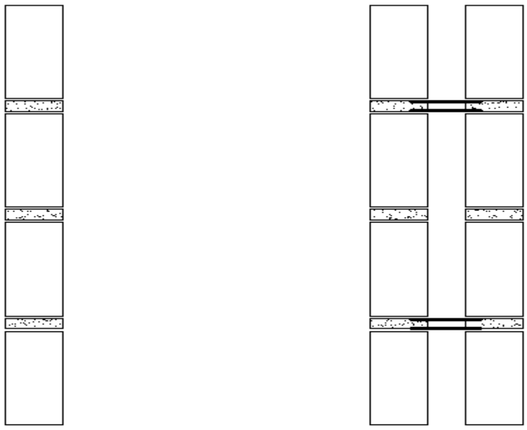
2.4.1 Aggregates

Thermal properties of aggregates have a decisive influence on the exposure of concrete in fire. In general, those aggregates previously heated for manufacturing can perform better in fire. Concrete made with blast furnace slag aggregates can deal with temperatures over 2000ºC; whereas, concretes made of limestone or dolomite can deteriorate severely at 900ºC [50]. Other researchers like Erlin and Hime [74] argue that this decomposition is at 750ºC.

Concrete exposed to fire can experience serious damage that can be from minor cosmetic blemishes to external cracking, delamination and spalling, internal microcracking, and chemical changes [75].

2.4.2 Masonry construction type

Figure 35 shows the most typical masonry construction type:



a) b)

Figure 35: Types of masonry construction: a) Single leaf; b) Cavity.

Single leaf masonry type is the most studied case in fire [76,77]. Its behaviour is mainly influenced by thickness when heated on one side; and is also affected by the mechanical and thermal properties of units and mortar.

The cavity consists of two single leaf walls forming a hollow that can be unfilled or filled using different materials or elements. It is designed to withstand the effects of sound, humidity and different temperatures.

In general, cavity walls have excellent fire resistance; some standard fire tests have demonstrated their excellent performance with some walls able to resist up to 4 hours or more without significant damage [78,79].

2.4.3 Masonry walls size

The total height of the walls influences the general behaviour when subjected to standard fire tests. It has been observed that walls greater than 3m in height can collapse earlier as a result of marked thermal curvature at mid-height caused by lateral displacement [16]. However, owing to a high cost and physical limitations of standard furnaces, testing walls greater than that size is seldom carried out.

Actual fire resistance codes do not specify limits to define total heights for walls. But in practice, less than 3m has been quite accepted [5,80,81]; in part, this has been adopted due to old specifications given at BS 476-20 [12], which recommends at least 3m x 3m specimens. Recently, as a measurement to reduce general costs in testing on half and full scale specimens, smaller specimens known as wallettes have been implemented successfully [82,83,84]. Plenty of benefits are derived from the wallettes, but the most important is the guarantee to simulate with good precision the same behaviour as that in larger walls.

Wallettes have been successfully adopted to determine the compressive strength [82,83] and shear [85] at ambient conditions. Although wallettes are limited to 1m in height [86], knowledge of the interaction unit-mortar is necessitated in order to have a more complete understanding of the behaviour of walls. Therefore the interest of using wallettes to study fire-behaviour should be based on determining their minimum size to have a minimum area to be exposed, but this area should also be sufficiently large to study the whole interaction of all masonry components.

2.4.4 Shape and material units

Both the shape and material used in masonry units influence the behaviour of walls in fire. Solid units have a good stability during fire attributed to their good homogeneity in comparison with other shapes. Cellular and hollow units have been applied successfully to determine the fire resistance of walls. They are designed to interrupt the passage of heat from the hot side to the cold side. This is achieved through the air contained in their holes and consequently that effect reduces the possible heat damage. This remarkable ability has caused increasing interest from researchers [77,87].

Units with a high level of perforations can develop large discontinuities in the way of heat flow across the wall. In addition, due to the absence of material in those perforations, the insulating capacity of the wall is affected [1]. Some codes assume that units with 25% of perforations have no effect on the insulating capacity of the wall.

Clay units can perform excellently well in fire due to lower thermal conductivity (about 0.25W / (m*K)) and thermal expansion principally. Some investigations have emphasized the high ability of clay units to maintain their strength without substantial variation up to 1000ºC [1], this may be attributed to previous exposure at high temperatures during the manufacturing process and to good thermal properties.

In general, concrete and calcium silicate units deteriorate rapidly over 500ºC. This is generally due to the removal of an amount of water of crystallization and a transformation of quartz and a subsequence expansion [51].

2.4.5 Heating rate

The heating rate is a measurement used to calculate how efficiently and fast the heat energy is taken by a material.

Experimental investigations on lightweight concrete have been reported by Schneider [33] using a heating rate of 4ºC/min. More research has been conducted applying rates of 1ºC/min [12], 5ºC/min [24]. The most recently reported rates were 2.5ºC/min [27] and 5ºC/min [88] to determine the residual compressive strength and coefficient of thermal expansion of lightweight concrete respectively. In general, variation in the residual mechanical properties was not reported from these rates.

The unique evidence of heating rate on mortar is reported by Shoaib et al [73]. The authors reported 10-20ºC/min applying to 7.5x15cm cylinders in order to obtain the reduction on the compressive strength. Although significant effects on this were not described, it is assumed that this rate was used to accelerate the decomposition of blast furnace slag which was one of the main components in the mixture.

2.4.6 Loading rate

Loading rate is needed to induce material failure for a specified time.

It is currently apparent that available information on loading rates to be applied in lightweight concrete tests is very restricted. Hammer [26] applied 0.8MPa/sec to estimate the reduced compressive strength at elevated temperatures. European Standard EN 772-1 [89] specifies loading rates which vary depending on the nominal compressive strength of the units.

Kelsey and Biswas [90] tested three epoxy mortars under compressive and tensile loads over the range of -35ºF to 200ºF. Loading rates from 1.27 mm/min to 2.54 mm/min for compressive tests and 0.254mm/min for tensile tests were used. The most significant conclusions were that all mortars exhibited a linear behaviour when the loading rate was in the range between 1.27mm/min and 2.54mm/min.

Cülfik and Özturan [6] employed a loading rate of 0.25MPa/sec, which is the range specified at ASTM C39 [65], to determine the compressive strength of mortar cylinders at elevated temperatures. However, important effects of this rate were not mentioned.

For testing wallettes to determine the compressive strength, European standard EN 1052-1 [86] suggests loading rates which vary from 0.15N/mm^2 per minute for low strength units to 1.25N/mm^2 per minute for high strength units. But the code demands that the tests are finalized between 15 to 30 minutes.

2.4.7 Spalling

Spalling refers to the breaking of fragments or pieces from concrete, brick, or stones, when exposed to intense heating conditions. Multiple investigations have been carried out in this field to identify its principal causes, but it is still considered as an unpredictable phenomenon. At present it is generally accepted that spalling is mainly associated with the effect of moisture content in concrete; which for lightweight concrete is critical over 5% by volume and if a concrete section is not less than 80 mm thick [91,92].

Significant research of spalling on lightweight concrete has not been reported, the principal factors suspected of producing spalling can be cited as follows.

These factors and their sub-categories can be considered as for normal and lightweight concretes:

a) Moisture
- Vapour pressure
- Moisture clogging
-Vapour pressure enhanced by frictional resistance of the underlying layers of concrete

b) Stresses resulting from:
- Initial compression
- Initial compression + thermal stress
- Initial compression + thermal stress + stress caused by frictional resistance

c) Cracking
- Aggregate expansion
- Internal cracks
- Reinforcement expansion

Spalling may also be influenced by rapid heating, number of faces exposed to fire, chemical composition of the cement, aggregate type, large compressive stresses, loading, restraint to thermal expansion, pore pressures [93], etc.

Types of spalling are classified as follow:

- *Explosive spalling* – This usually occurs during the first 30 minutes of a heating phase and over 100ºC. At which, large or small fragments of concrete can be violently expelled from its surface, accompanied by a loud noise. It can happen just once or at intervals of time and even from the previously spalled parts. This type of spalling is more common in high strength concrete [94]. The severity of explosive spalling can lead to the formation of holes through the thickness of the section.

- *Surface spalling* – This is associated with local removal of surface material including pitting and blistering. This occurs when 20 mm pieces fly off the surface during the early parts of its exposure [94].
- *Aggregate splitting* – It is characterized by a popping sound. This kind of spalling is caused by thermal expansion of the aggregate and splitting of aggregate pieces near to surface, this is attributed to physical or chemical changes at high temperatures. It has been reported that at 570ºC quartz is converted into limonite-haemetite causing the splitting of the aggregate.
- *Corner separation* – It appears during the ultimate phases of a fire, this is when concrete becomes weaker and cracks are developed owing to tensile stresses along edges and corners where the reinforcement is usually located. In this spalling, fragments of concrete fall off from beams and columns, and in some cases are followed by pieces coming away from the faces where cracks develop.
- *Sloughing off* – This is produced by chemical deterioration of cement paste and internal cracking of concrete due to the difference in thermal expansion between the aggregate and the cement paste [95]. This type of spalling is more associated with the attained temperature level than with the heating rate.
- *Post cooling spalling* – Carbonate aggregates in limestone expanding on re-hydration during the cooling phase of a fire are the main cause of this spalling, which is characterized by a silent non-violent process.

Although spalling is more associated with concrete, it has seldom been reported to occur in mortar. The unique reported investigations have concluded that spalling is mostly presented at over 600ºC on high strength mortar, heated with a very rapid rise [62].

2.4.8 Types of failure

Experience on standard fire tests has demonstrated that walls fail due to the following factors:

a) Thermal bowing
b) Eccentricity

a) Thermal bowing

This phenomenon has been previously studied [3,4]. Thermal bowing is an effect in single structural elements that are not fixed at the top and exposed to fire on one side. Clay and concrete walls develop high temperature gradients over the cross section attributed to their low thermal conductivity. The distribution of the temperature is then markedly curvilinear. Differential thermal expansion causes expansion of the heated face more rapidly than the cooler face, besides this expansion produces bending towards the fire location. The fire-exposed face suffers a considerable deterioration causing a reduction in thickness; which affects the eccentricity of in-plane loading. The criterion to evaluate its damage is dominated by general consideration of deflections, which should not be greater than the original thickness of the wall. Some conditions can favour its occurrence such as:

-Materials with higher coefficient of thermal expansion

-Increasing the temperature difference between exposed and unexposed surfaces

-Cantilever walls

-Short distance between the exposed and unexposed faces

b) Eccentricity

Eccentricity has been demonstrated to take place on separating walls; the effects of fire on one side will produce a thermal curvature that will induce eccentricity and this will accelerate its structural failure.

It has been observed that in the case of loadbearing wall fire tests, sandwich panels usually placed between the wall and the top-bottom platens play an important role because they distribute the loads across the thickness of the wall [2]. At initial phases, the load is uniformly well distributed across the thickness of the wall (Figure 36a). But as the wall starts to curve towards the fire side, top and bottom ends of the wall will rotate and change the load distribution with the load migration towards the fire (Figures 36b and 36c).

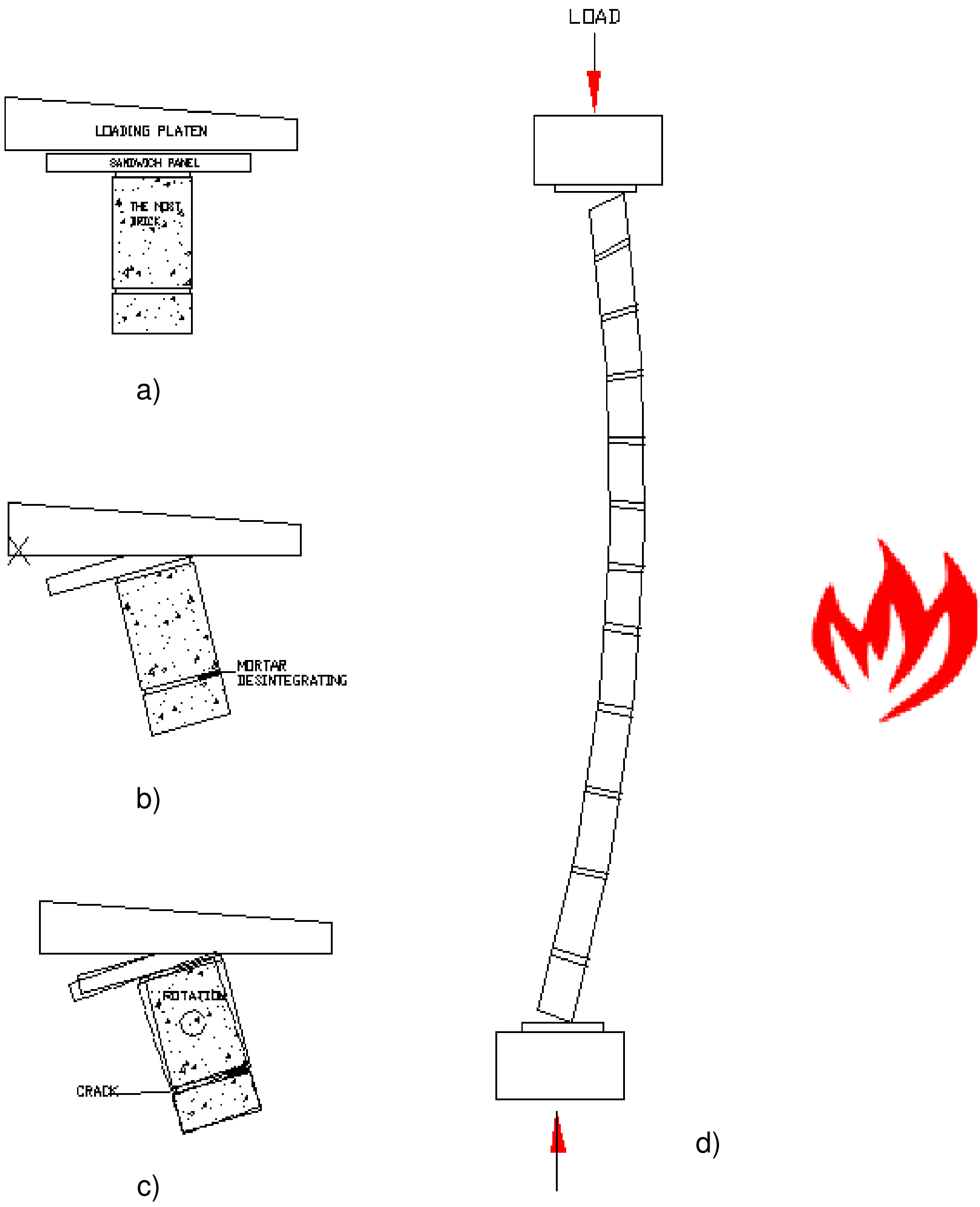


Figure 36: Section through a brick wall exposed to fire [2].

2.4.9 *International fire design masonry codes*

Table 2.2 summarises some international codes and standards dealing with structural fire design of masonry.

Table 2.2 International fire masonry design codes.

Region	Nomenclature
Europe	BS EN 1996-1-2 [7]
Great Britain	BS 5628-3 [14]
Germany	DIN 4102-2 [96]
Finland	NKB 1994:07 [97]
Canada	CAN4-S101 M89 [98]
United Stated of America	ASTM E 119 [99] ACI 216.1 [100]
Australia	AS 1530.4 [101]
Japan	JIS A 1304 [102]
New Zealand	NZS 3101-1 [103]
Norway	NS 3473 E [104]
International	ISO 834-8 [13]

These design codes and standards are usually applied to determine the fire resistance of masonry walls in these countries. The concept is very similar in all of them which evaluates the duration for which the types of walls made in those countries can retain their structural stability during predetermined test exposure. The following are some differences that have been identified:

- The most significant variation is found in the temperature-time curve adopted for the tests. The most of them use the temperature-time relationship from [13], however, small differences can be found in the curves adopted by [99, 101 and 103].

- There are some differences in the number of specimens to be tested. The German DIN 4102 [96] requires 15 repetitive tests for complete tests or 3 for indicative ones.

- The dimension in the specimens exposed to fire is another small difference found in these codes. Eurocode 6 [7], The British Standard [14], The Australian code [101] do not specify any dimension for specimens, but the German Code requires dimensions of 90x230mm and 90x190mm.

Chapter 3

Experimental programme

3.1 Introduction

The chapter discusses the comprehensive experimental programme carried out by the author in order to study the behaviour of masonry wallettes in fire as an effective way to reproduce the thermal behaviour of full size masonry walls.

Full details of the different phases for the construction, curing, and testing of the masonry specimens are herein described. Moreover, the test rig designed for the compressive tests at elevated temperatures is shown.

Experimental research on the behaviour of lightweight concrete solid blocks belonging to the same batch used for the masonry wallettes at thermal conditions is also included. The information presented in this chapter contains the procedures used to prepare the blocks before being tested and to test them.

Furthermore, a programme to study the behaviour of mortar with temperature is presented. The aim is to evaluate the reduced tensile strengths of the mortar.

3.2 Experimental programme

The programme was structured into the following phases:

3.2.1 Phase 1

In this phase, the influence of fire on masonry wallettes was investigated. The variation of compressive strength and other elastic properties were evaluated. The specimens were tested at room temperature and in hot conditions. Steady state was the thermal condition applied for those wallettes considered to be heated. The target temperatures were: ambient, 200ºC, 400ºC, 600ºC, 700ºC and 800ºC. A full description of the different stages for the manufacturing, curing and testing phases are presented in this chapter.

3.2.2 Phase 2

For this phase, a specified number of lightweight concrete blocks were exposed to the same test conditions as those applied to the wallettes; the main objective of this test was to estimate the reduced compressive strength at elevated temperatures. The blocks belonged to the same batch used for the construction of all the wallettes.

3.2.3 Phase 3

In this stage, mortar behaviour was mainly investigated under hot conditions. Mortar briquettes or “dog bones” shape specimens were cast to determine the reduced tensile strength by applying similar thermal conditions defined for masonry wallettes previously. Nine mortar briquettes were cast and cured to investigate their behaviour, based on a direct tensile test, at ambient, 200ºC, and 400ºC. Mortar specimens were made from the batch used in the wallettes.

Full details of each test are presented in this chapter.

3.3 Materials

The materials used for the experimental programme are presented as follow:

3.3.1 *Cement*

Cement was one of the principal components for this research; with a composition conforming to requisites given at BS 12 [105] and BS EN 197-1 [106]. Full details of this composition can be found at Appendix A.

3.3.2 *Lime*

The hydrated lime (CL 90) used for mortar complied with BS EN 459-1 [107]. This type of lime is non-hydraulic, suitable only for cement mortars.

3.3.3 *Sand*

Natural sand based on BS 882- [108] was incorporated in the mortar mixtures for this experimental investigation.

3.3.4 *Water*

Manchester tap water was added to the mixtures in this research, water was specified according to BS EN 1008 [109].

3.3.5 *Blocks*

Lightweight concrete blocks were used for the wallettes; standards dimensions of 440x215x100mm were selected. The nominal design compressive strength was 7.3N/mm^2. The blocks were manufactured to the requirements given in BS 771-3 [110] and BS EN ISO 9001 [111]. Their composition is found at Appendix A.

3.3.6 *Insulating materials*

Isofrax blanket and Calsil board were the insulators used to protect some parts of the test rig against the effects of high temperatures, their fabrication is covered by BS EN 1094-1 [112].

3.3.7 *Thermocouples*

Type K thermocouples were employed to measure temperatures from specimens.

3.4 Geometry

Figure 37 shows the geometrical properties used for the wallettes; each specimen consisted of three courses containing half and whole blocks, 10mm vertical and horizontal mortar joints were also used. Both top and bottom faces were capped with the same mix used for the joints. The locations of all the thermocouples used are also indicated in the same Figure.

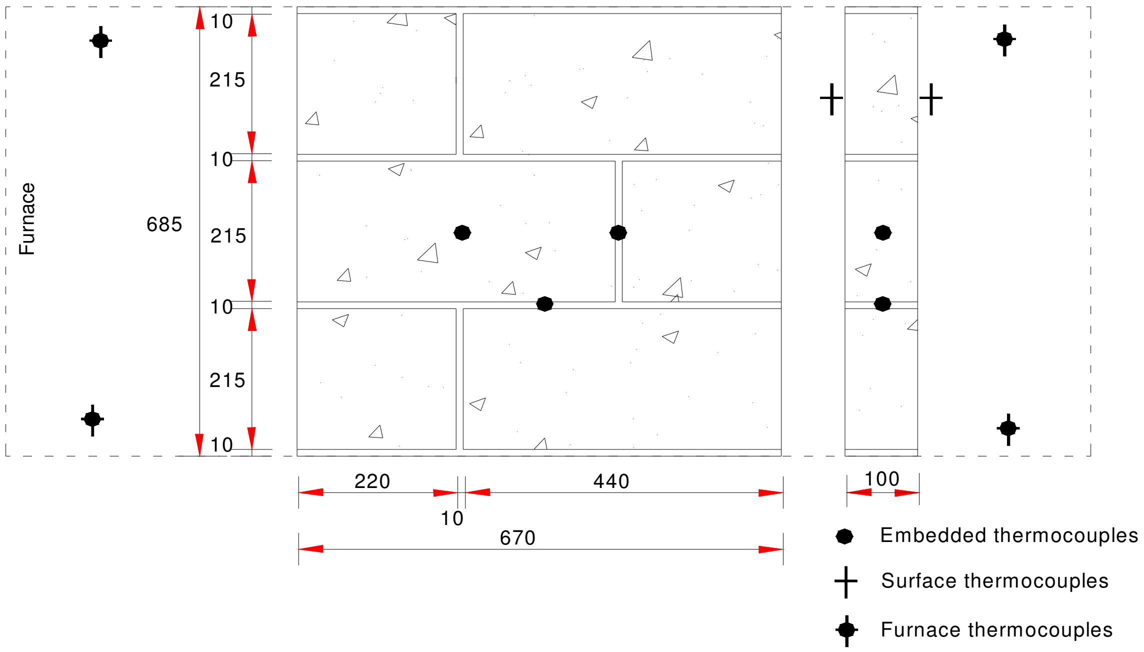


Figure 37: Geometry of masonry wallettes.

This geometry was designed following BS 1052 [86], and is presented in Table 3.1. It is noteworthy that these conditions are applicable for specimens not greater than 1000mm. In addition, it is worthy of mention that by applying these geometrical conditions, the specified critical slenderness ratio was satisfied according to BS 1996-1-1 [63], which establishes a maximum permissible value of 27.

Table 3.1 Geometrical requirements for masonry wallettes [86].

Face size of unit (mm)		**Masonry specimen size**			
Length (lu)	Height (hu)	Length (ls)	Height (hs)		Thickness (ts)
≤ 300	≤ 150	≥ (2*lu)	≥ 5 hu	≥ 3 ts and ≤ 15 ts and ≥ ls	≥ tu
	> 150		≥ 3 hu		
> 300	≤ 150	≥ (1.5*lu)	≥ 5 hu		
	> 150		≥ 3 hu		

3.5 Test rig

A test rig to carry out the compressive strength tests of the wallettes at elevated temperatures was specially designed by the author. Figure 38 illustrates the different stages during its construction. The test rig comprised the following parts:

a) Heavy steel frame

The frame consisted of two steel columns connected at the top by a pair of 380x100mm flange steel channels and at the bottom by another two 430x100mm flange channels by using base plates. The bottom channels were bolted down to the laboratory floor (see Figures 38a and 38b). A large 12mm thick steel plate was placed on the bottom channels to support the furnace and the specimens. Both top and bottom flange channels were stiffened at mid-length to withstand possible severe local buckling due to vertical loads.

a) b)

Figure 38: Heavy steel frame used for compressive strength tests at high temperatures.

The reaction frame was designed to make all its components removable and to facilitate its displacement at the time of inserting new specimens into the furnace, which was reached with the aid of a mechanical crane.

b) Loading system

The loading system comprised a 100KN hydraulic jack and a 140KN load cell (see Figure 39a). The loads were applied through a spreader beam (see Figure 39b) supported by two rollers which transmitted the load with a 60mm thick steel solid bar to the specimen. The bar, which was on the top of the specimen, was attached by threaded steel bars to the reaction frame to prevent it falling into the furnace when the wallettes collapsed. The hydraulic jack was activated by the use of a manual pumping machine.

a) b)

Figure 39: Loading system in the test rig.

a) b)

Figure 40: a) Linear potentiometers, b) Tubular frame to attach potentiometers

c) Measuring system

Vertical deflections were measured using two 100mm linear potentiometers attached to an independent tubular frame (Figure 40b). The “Linpots” measured any vertical movement which occurred in a 10mm steel plate located between the hydraulic jack and the load cell (see Figure 40a). These potentiometers were positioned to a certain distance each complying with specifications at BS 1052 [86].

d) Heating system

The electrical furnace was a rectangular DaVinci able to heat up to 1100ºC and to apply a rate of 10ºC/min (see Figure 41). The furnace was formed with three panels. A special lid was designed for the furnace, which composed of a steel frame and was insulated with a combination of blanket-calsil-blanket layers. The lid was divided in two parts so that it could slide easily into place.

Figure 41: DaVinci furnace used to heat wallettes.

Temperatures, loads and deflections were recorded with the use of a data logging system and a computer. All temperature measurements were recorded at 30sec intervals; while intervals of 2sec were applied for loads and deflections.

3.6 Specimen manufacture

3.6.1 Mortar specimens

Nine standard briquettes were included to determine the tensile strength at some of the target temperatures used for the wallettes. Three specimens were tested at the same hot conditions from room temperature up to 400ºC.

The tensile test samples were manufactured according to American Standard ASTM C39 [65]. One thermocouple was positioned inside the specimens to be exposed at thermal conditions.

3.6.1.1 Mix design

M2.5 was the designation for the mortar used in wallette construction [63,86]. The mixture consisted of Portland cement, hydrated lime, and sand in a proportion of 1:1:5 by volume, 1.7 by weight was the water/cement ratio used for the mix. Due to the capacity of the cement mixer, four batches were required to prepare the mortar for the wallettes and the other specimens, Table 3.2 summarises the mortar batches:

Table 3.2 Mortar mix used.

Batch	Portland Cement (Kg)	Hydrated lime (Kg)	Sand (Kg)	Water (Kg)
1	8.0	3.8	49.3	13.4
2	8.0	3.8	49.3	13.3
3	8.0	3.8	49.2	13.5
4	8.0	3.8	49.1	13.4

3.6.1.2 Mixture phase

The mortar was made in a rotating cement mixer; cement and sand were initially stirred until a uniform mixture was achieved. It was then observed to ensure it did not contain lumps at this phase; subsequently lime was gradually added until the mix looked smooth. Finally water was added and distributed in such a way to avoid lumps and other imperfections.

To ensure the good workability in mortar, two particular steps were taken: visually the mortar was judged by an experienced bricklayer and a standard flow test was carried out, for which average values of 115% were measured. These are the standard values for good mortar workability [29]. Figure 42 shows some aspects during this test.

Figure 42: Mortar flow test.

3.6.1.3 Casting and curing

The mortar used for tensile tests and other type of tests with temperature was cast in standard moulds on a vibrating table as shown in Figure 43.

Figure 43: Mortar casting.

The moulds were previously oiled to prevent mortar adhering and to facilitate specimens when they were dismantled. After being cast, mortar specimens were wrapped in polyethylene to avoid premature drying out, being removed from moulds after 24 hours. The mortar specimens were then cured at air-dried conditions.

Figure 44: Mortar curing.

3.6.2 Lightweight concrete units

The blocks, those expected to be tested individually at room and hot conditions, were prepared conforming to BS EN 772-1 [89]. Mortar capping was selected as the surface preparation method for units to be used for compressive tests. Prior to be used for the wallette's construction, the blocks were stored in air-dry conditions.

The process of unit capping is explained in the following steps (see Figure 45):

- This work was developed on a rigid table. Glass sheets with proportional dimensions to the block's size were used to cap the units; a thin layer of oil was applied on the glass to avoid any mortar adhering and to facilitate the easy removal of the blocks (Figure 45a).
- A rectangular wood frame was designed to ensure a maximum layer of mortar of 5mm; the frame was then placed on the top of the glass sheet (see Figure 45b).

a) b) c) d) e) f) g) h)

Figure 45: Phases of capping for lightweight concrete blocks.

- A mortar proportion of 1:1 (cement:sand) in volume was made to cap the blocks. An amount of mortar was deposited in the frame, and then extended along the hole in the frame. Meanwhile, one side of the frame guided to reduce mortar layer until the specified uniform thickness was reached (see Figures 45c and 45d).
- The blocks were then embedded and pressed down into the mortar layer using a rubber mallet. A spirit level was used to ensure that the axes of the units were perpendicular to the plane of the plate (Figure 45e).
- A trowel was used to remove the excess of mortar in order to get regular edges (see Figure 45f), and then the blocks were covered with plastic sheets for curing for at least a half day.
- Later the blocks were checked for any defects in the capped face, then the opposite face was capped following the same procedure (Figure 45g).
- When both faces had been capped, the blocks were left on a platform in order to comply with a curing period of 28 days at dry room conditions (Figure 45h).

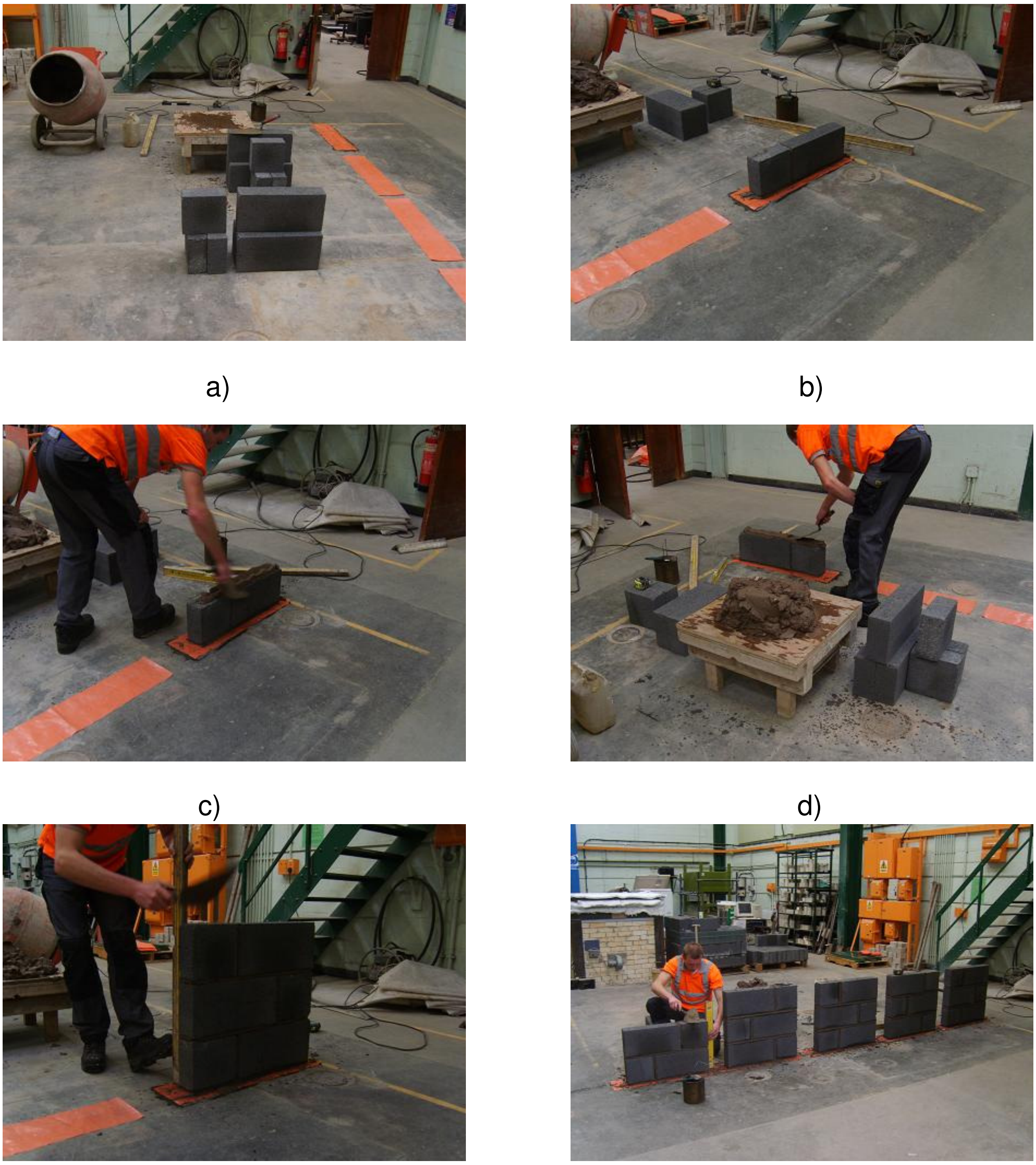
Some blocks were cut in half through a diamond cutting wheel machine to complete with the specified dimensions for the wallettes. Those blocks were previously immersed in water to facilitate their cut.

3.6.3 Wallettes

Eighteen masonry wallettes were built to investigate the influence of high thermal conditions; another three specimens were also included to repeat some tests. The specimens were made of a standard mortar and lightweight solid concrete blocks. Whole and half blocks, 10mm mortar joints were used to complete with dimensions of 685x670x100mm. The wallettes were manufactured based on BS 1052-1 [86] and EN 1996-1-2 [7]. Full details of the construction process are as follows:

- This experiment was developed at the fire laboratories in the University. The wallettes were constructed by an experienced bricklayer.

- Initially some plastic sheets, with proportional dimensions to the wallettes, were put in a clean solid free area. Those sheets were previously cleaned and greased with oil to avoid mortar adhering (see Figure 46a).



a) b) c) d) e) f)

Figure 46: Phases of manufacturing for the masonry wallettes.

- Figures 46b and 46c show the general details during the construction of the first wallette. The blocks were placed in normal aspect orientation.
- Mortar was fabricated with the use of a cement mixer and was then deposited on a small table to make its application easier (see Figures 46a and 46d).
- To get uniform sides in the wallettes, a spirit level was used (Figure 46e).

a)

b)

c)

d)

e)

f)

Figure 47: Capping and curing phases of the masonry wallettes.

- Wallettes were placed to make rows of 5 specimens each. The same sequence was used when they had been tested (from left to right in the picture), this is shown in Figures 46f and 47a.
- Once the wallettes were constructed, a process of capping continued. The same mortar type used for wallettes was applied for a 10mm capping layer. Glass sheets were employed to cap the top faces of the specimens. With the use of a rubber mallet and a spirit level, a perpendicular plane to that in the floor was reached at the top face of specimens (see Figures 47b, 47c, and 47d).
- All wallettes were covered with polyethylene in order to avoid premature drying out for the first three days after their construction; this stage is shown in Figures 47e and 47f. At the same day of construction, two thermocouples were inserted inside vertical and horizontal joints at each specimen.
- Figure 48 illustrates the final curing phase of the wallettes; they were reserved in laboratory conditions at a temperature of 20ºC±5ºC and a relative humidity of 45%.

Figure 48: Final phase of the masonry wallettes.

The first wallette was tested at the age of 88 days, but for subsequent specimens this age increased due to the time taken to cool down the furnace and the other parts until normal conditions.

3.7 Test procedures

This section highlights the procedure used for testing the wallette specimens exposed to ambient and steady state thermal conditions. The methodology for heated and unheated block tests is here described. Eventually this section contains details of the testing process in the determination of tensile strength with temperature.

3.7.1 Mortar tests

Although specimens were cast to test mortar under compression and tension at high temperatures, the procedure to obtain the tensile strength is only shown because it was the unique mortar test carried out.

3.7.1.1 Direct tensile tests

The test methodology to determine the tensile strength of mortar at elevated temperature is presented in this section. The test setup consisted of a small electrical furnace able to heat up to 1100ºC and to control standard heating rates, such as 10ºC/min. A Lloyd instrument testing machine was used to simulate the tensile loads. This machine was capable to control standard loading rates with a high precision. A computer was used to read the tensile deflections, loads and temperatures.

Figure 49: Test setup for determining mortar tensile strength at high temperatures.

The furnace had a hole on its lid, which was used to remove the specimens once they were heated. During the heating phase this hole was shut by using a combination of blanket-calsil board-blanket coats. A general view of this test setup is illustrated in Figure 49.

To reproduce equal test conditions applied in the wallettes, the same heating rate used on them was applied to the mortar briquettes, which was 10ºC/min. Meanwhile, tensile loads were applied in a rate according to ASTM C307 [113], which states from 5 to 6.4mm/min for tensile mortar tests. A rate of 5mm/min was therefore used for this work. The temperatures were measured at intervals of 30sec each. Using that loading speed and in accordance with the expected strength, a short time was required for the tests.

For unheated tests, the mortar samples were carefully placed in the machine. With the clips properly adjusted to briquette's size, the specimen was then loaded until failure occurred. Figure 50 presents some details of the tensile test of mortar briquettes.

Figure 50: Tensile test of mortar briquette at room temperature.

In the case of the specimens to be subjected to thermal conditions, the furnace was heated with a rate defined previously. The mortar samples were then left inside until thermal equilibrium occurred.

Figure 51: General view of tested briquettes at elevated temperatures.

One thermocouple was placed in some briquettes to guide for the temperature distribution and to take the average temperature. The mortar specimens were tied from their thinner parts by fire resistant wires, whose ends were left outside the furnace to facilitate their exit (see Figure 51). Subsequently, the specimens were taken one by one out and the wires were cut to avoid any problem with the clips. Eventually the specimens were brought to the Lloyd machine and tested rapidly.

The time taken between the moment of removing the specimens from the furnace and the moment of testing them in the tensile machine was approximately less than 1min. Therefore, the effects of the transfer process were felt to be negligible.

3.7.2 Block test

Testing blocks under identical hot conditions to those for obtaining the reduced compressive strength of the wallettes was another objective of this research. The conditions for the testing process were based at BS 772-1 [89]. The test rig used for wallette compressive tests was adapted to test the blocks. Originally composed of three panels, the furnace was then conditioned to only one. The top flange channels were moved down sufficiently to adjust the loading system on the block's geometry as shown in Figure 52.

Figure 52: Test rig used for blocks at elevated temperatures.

The tubular frame, on which the potentiometers were attached, was also moving down at the same level of that steel plate to measure the deflections.

The vertical uniform pressure was applied using a rate of 0.005 (N/mm^2)/s, which is suitable for units with a lower strength than 10N/mm^2 [89]. Although the hydraulic jack was driven manually, it was activated following a loading plan to achieve the defined rate. This plan consisted of a time-load relationship based on the expected unit compressive strength.

To control the temperature rising, a 1.5mm diameter hole was drilled in the centre of the block for inserting one thermocouple, while another was fixed at its surface. Temperatures were measured at the same time intervals as for the wallettes; loads and deflections were also read at each 2sec intervals. Steady state was used as the thermal method to test the blocks.

The transportation of blocks was carefully carried out from the curing places by hand and deposited in the test rig. It was ensured that both the top and bottom block surfaces were completely clean and free of small particles that could have affected the test. Bearing surfaces of the bottom and top testing plates were also wiped. The blocks were aligned with the centre of the top 60mm thick plate.

The unheated tests consisted of inserting a block in the test place and loads were then applied with the specified rate up to failure. Loads and deflections were recorded and the strength was therefore calculated dividing the maximum load achieved by the block loaded area. For heated blocks, the unit was positioned in the electrical furnace and the temperature was elevated by using the same rate defined for wallette compressive tests, which was 600ºC/hour. The thermal equilibrium was achieved once the thermocouples inserted in the block showed the same target temperature value within ±10ºC. Finally the block was loaded until failure occurred.

To prepare new blocks for testing, sufficient time for cooling down was permitted. This was achieved by using the normal furnace cooling period. A total number of 5 blocks were tested at each temperature group. The average strength was then obtained.

3.7.3 wallette test

The heated masonry tests were aimed for the determination of mean and characteristic compressive strength in accordance with BS EN 1052-1 [86] and EN 1996-1-2 [7]; for which three wallettes needed to be tested at identical conditions. The masonry codes do not specify a pre-defined rate to apply on compressive tests; however, a period ranging between 15-30min is recommended to control the uniform compressive loads [86]. Consequently based on the expected strength of the wallettes and on that estimated time, average final loading rates of 10 KN/min were reached in this research.

To replace the wallettes in the furnace and to facilitate their incorporation, the reaction steel frame was moved by a crane as illustrated at Figure 53a. The specimens were transported from the curing location to the furnace in a lifting frame (see Figure 53b) made out of steel channel sections.

a) b)

Figure 53: a) dismantling test setup phase: b) Lifting frame to transport the specimens.

3.7.3.1 Unheated specimens

For unheated tests, the specimen was positioned inside the furnace as a security measurement to avoid any damage in equipment near to the test rig and in people. After, a uniform compressive load was increased steadily until failure occurred. General observations were focused on identifying if large deflections appeared at the loading point. Figure 54 shows a typical unheated test, the specimen was placed inside the furnace as a security measurement.

Figure 54: Masonry wallettes under unheated test conditions.

3.7.3.2 *Heated specimens*

For specimens under thermal conditions, the target temperatures were ambient, 200ºC, 400ºC, 600ºC, 700ºC and 800ºC. Five thermocouples (type K) were positioned inside each specimen to measure the evolution of the temperature; one was placed at the centre of a vertical joint, another at the middle of a horizontal joint, one more inside a block; two further thermocouples were fixed to the surfaces of the wallettes.

With a wallette positioned in the furnace, the temperature was raised at a rate of 600ºC/hour. The target temperature was then maintained until all thermocouples placed in the wallette registered the same value; the thermal measurements were taken with a precision of ±5ºC.

Once the thermal balance was achieved, the specimen was then loaded using the specified rate stated previously until failure was occurred. Vertical deflections and loads were then recorded. When the test ended sufficient time was permitted to allow the wallette to cool down. Figure 55 presents a general view of a heated test.

Figure 55: Masonry wallette after steady state test conditions.

Due to the hot conditions, there were some parts of the test rig more susceptible to be damaged than others. During this phase the load cell needed special attention, since it was affected by heat coming from the wallette. Therefore insulation was used to protect the cell (as observed in Figure 56) and an additional thermocouple was used to monitor the temperature in the load cell.

Figure 56: Masonry wallettes under unheated test conditions.

Chapter 4

Experimental results

4.1 Introduction

This chapter presents the experimental results carried out in the laboratory. First the results from the masonry wallettes exposed to elevated temperatures are highlighted; they are mainly based on the variation of the compressive strength but other aspects such as thermal features and failure modes are also included. Some investigations on the material degradation originated by fire are contained as well. For compressive tests, the results were initially obtained as load-deflection relationships and subsequently converted into stress-strain compressive relationships.

Secondly, the experimental investigations from individual lightweight concrete solid blocks under thermal conditions are presented. The reduced compressive strength is presented in conjunction with different aspects of material behaviour. Finally, research based on mortar specimens subjected to heat is presented. This refers to the experimental phases discussed in previous chapters.

4.2 Experimental results

4.2.1 Masonry wallettes

The experimental investigations of masonry wallettes exposed to hot conditions based on steady state tests are reported below.

4.2.1.1 Thermal behaviour of masonry wallettes

Six different temperatures were used to study the behaviour of the masonry wallettes, they were 20ºC, 200ºC, 400ºC, 600ºC, 700ºC and 800ºC, for which three specimens were tested. Figures 57 to 61 shows the typical temperature distribution obtained from one of the three wallettes tested at various temperatures. Five curves were plotted for all the graphics. The temperature in the furnace is denoted by "Furnace temp", this temperature curve is the average of four thermocouples placed inside the furnace at different positions. Another curve is the average of two thermocouples attached in the surface of the specimen; this is plotted as "Surface temp". Two curves measured the temperature inside vertical and horizontal mortar layers; they are denoted as "V mortar temp and H mortar temp" respectively. Finally, the curve that measured the temperature inside a block is distinguished as "Block temp".

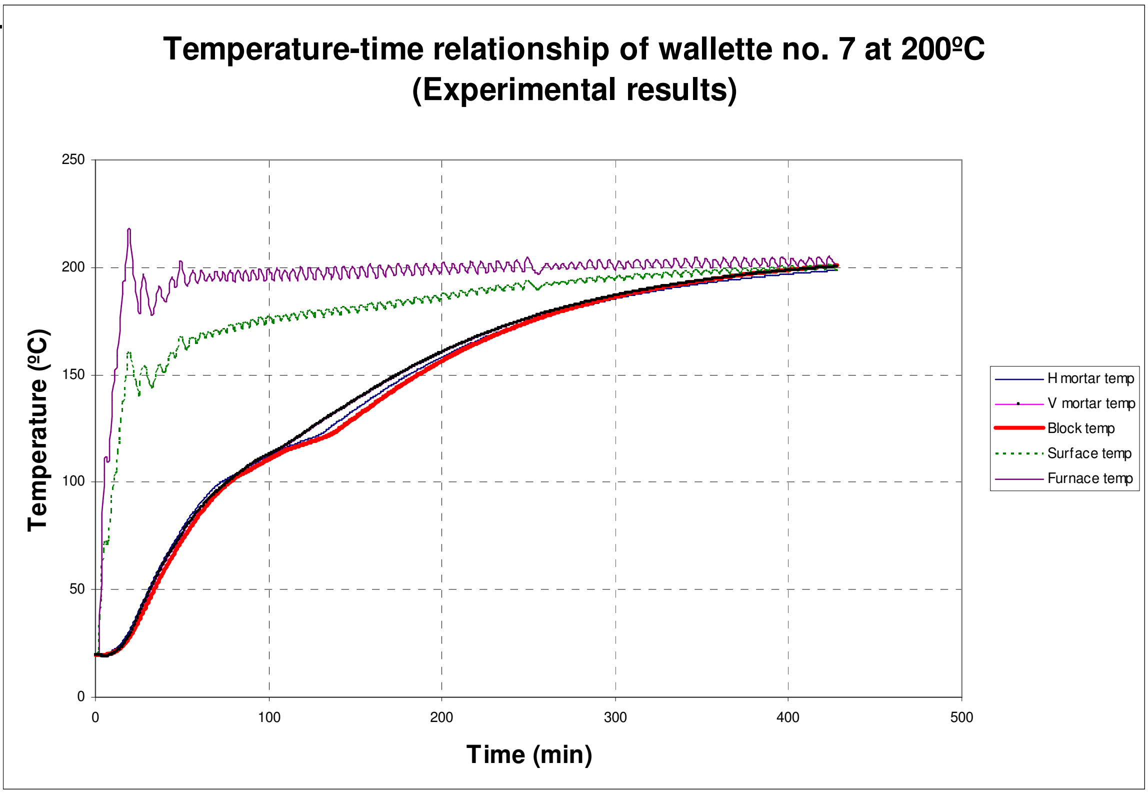


Figure 57: Typical temperature-time relationship of a wallette heated at 200ºC.

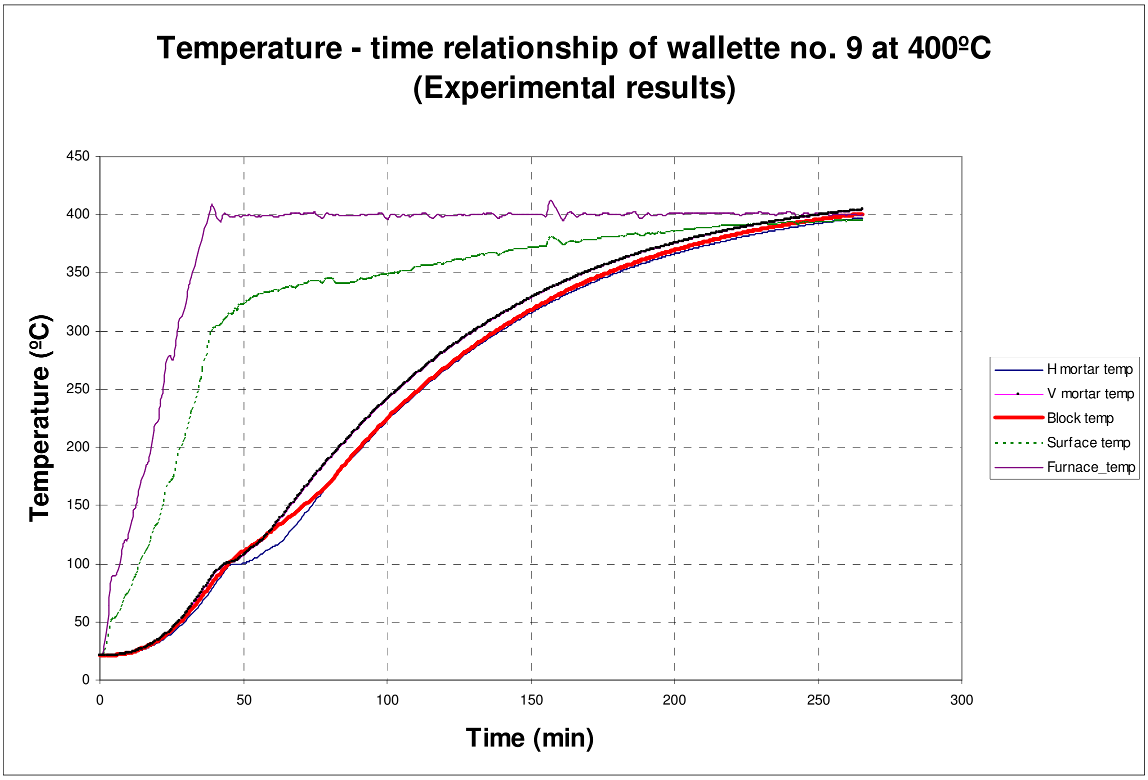


Figure 58: Typical temperature-time relationship of a wallette heated at 400ºC.

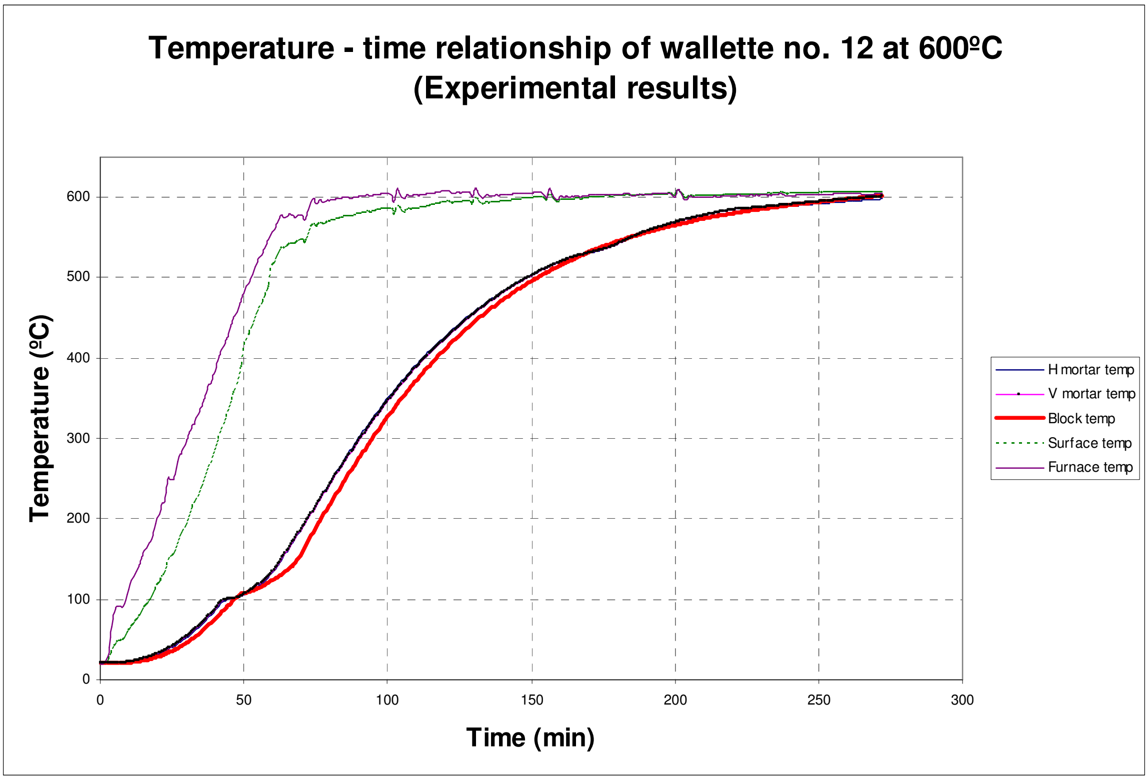


Figure 59: Typical temperature-time relationship of a wallette heated at 600ºC.

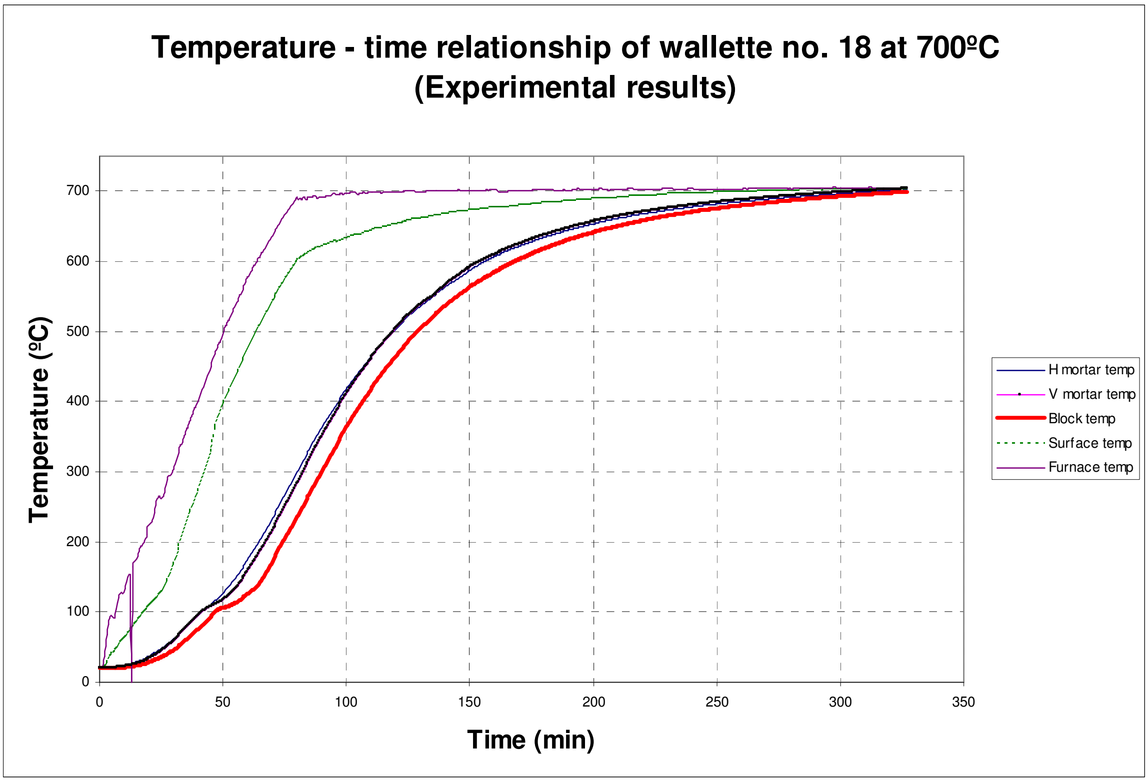


Figure 60: Typical temperature-time relationship of a wallette heated at 700ºC.

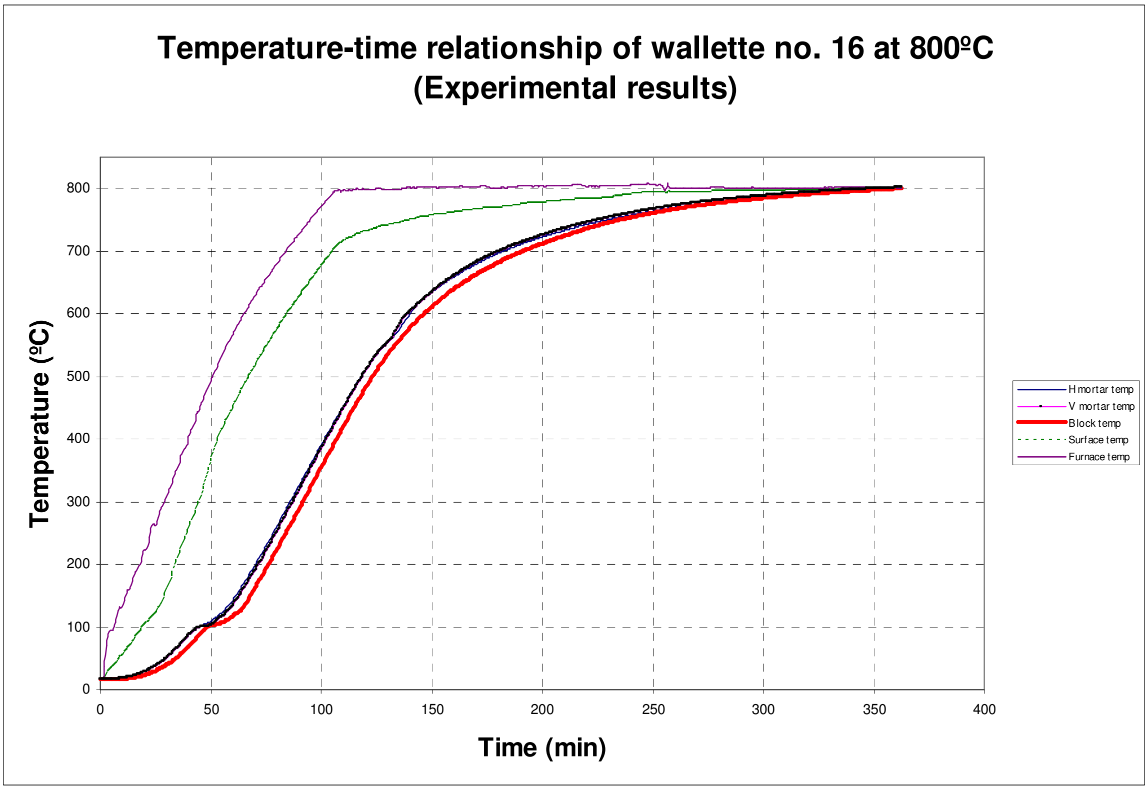


Figure 61: Typical temperature-time relationship of a wallette heated at 800ºC.

Some curves show a large peak especially in those used to measure the temperature inside the furnace at 200ºC and 400ºC; these peaks indicate some adjustments made to regulate the temperature of the furnace. Moreover, during the heating period of the first wallettes heat loss caused by an inappropriate insulation, was experienced and necessitated constant adjustments.

Moreover, the curve representing the surface temperature showed an irregular performance as a consequence of the type of adhesive used to fix the thermocouple to the surface of the wallettes. For the first wallettes, a strong, long lasting adhesive was used, which, in accordance with its specification was capable of withstanding up to 70ºC; resulting in erroneous temperature measurements. In fact, at the end of this phase, it was observed that the thermocouple initially attached from the surface was dropped into the base of the furnace.

For further tests, the Araldite strong adhesive was substituted with dental plaster, which retained the thermocouple in place at the wallette's surface during the heating phase and even after the tests.

From these graphics, it can also be observed that the curves from the horizontal and vertical mortar layers had a minor temperature difference, which was more visible at the range of 100ºC to 300ºC. On the other hand, all the temperature readings showed a thermal difference between the mortars and block curves; at the beginning of the heating phase this difference was without any substantial variation for the first 30min. After this, the difference was more consistent along the whole curve, but it was dramatically reduced near the last 50ºC or 100ºC. This difference explains clearly a better fire performance attributed more to the thermal properties of the block aggregates than those of the mortar.

Figure 62 summarises the curves of all the wallettes heated and tested for this work. These curves were obtained from the thermocouples embedded in the blocks, which were considered the most important location to give the best indication of the temperatures within the wallettes.

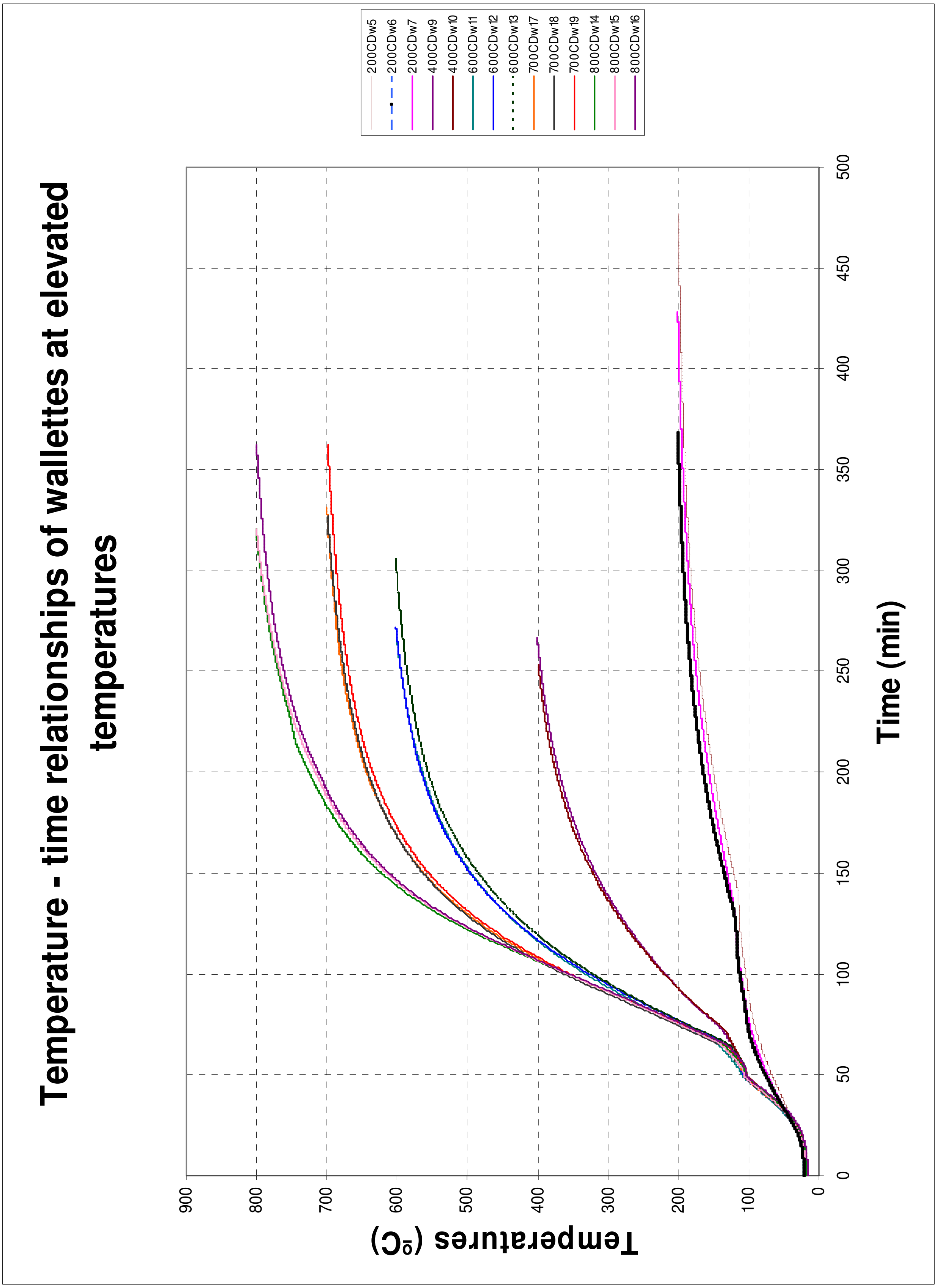


Figure 62: Evolution of temperature in the masonry wallettes.

From the same figure, it can be appreciated that all the curves were interrupted by the appearance of a "plateau" period, which is mainly associated with the energy absorption by phase-change (liquid water is transformed into vapour), which usually occurs at 100ºC. The plateau in masonry walls at elevated temperatures has been related to the effects of the high permeability of the block aggregates and gas pressure contained in the pores [77].

The duration of this plateau is linked with the time taken for the water contained in the pores to be completely evaporated and with the target temperatures. The duration of the plateau for the wallettes tested at 200ºC was significantly longer than that for the wallettes tested at higher temperatures, which was approximately 55min. The experimental results revealed that the average time for the plateau was 27min for wallettes tested at 400ºC, 18min for wallettes at 600ºC, 17min for wallettes at 700ºC and 16min for wallettes tested at 800ºC.

From Table 4.1, it can also be observed that the duration for the heat transfer in all the specimens varied significantly. The wallettes heated at 200ºC took a considerable time in comparison with the other wallettes heated at higher temperatures.

Table 4.1 Duration of thermal equilibrium in heated wallettes.

Duration for the thermal balance	
Target temperature (ºC)	**Time (min)**
200	425
400	262
600	281
700	341
800	335

The main factors that could have influenced the thermal behaviour of the masonry wallettes were: target temperatures, heating rate, moisture content, and the thermal properties of both mortar and blocks. From the results of this research, it can be noted that the wallettes tested at 200ºC demonstrated an unpredicted behaviour in terms of the total duration for the heat transfer and for the plateau periods. For the particular case of the wallettes tested at 200ºC, the heat loss was assumed to be the most important variable influencing their behaviour induced by an insufficient insulating method.

4.2.1.2 *Stress-strain compressive relationship*

The stress-strain compressive relationships of the masonry wallettes tested in fire are presented at this stage. Table 4.2 summarises the geometrical properties of the wallettes constructed for testing at elevated temperatures, all dimensions were measured from three different points on each specimen and their corresponding average dimensions are finally shown.

Table 4.2 Geometrical properties of the masonry wallettes.

Masonry wallettes				
Wallette designation	Properties			
	Weight (Kg)	Ave height (mm)	Ave length (mm)	Ave thickness (mm)
1	64.3	690	667	98
2	62.2	686	667	97
3	62.0	685	669	98
4	61.2	689	666	98
5	61.6	691	668	97
6	61.9	687	668	98
7	61.0	688	665	97
8	61.3	686	665	97
9	61.6	687	667	97
10	61.6	690	666	97
11	62.0	684	667	97
12	61.7	686	666	97
13	61.5	690	666	97
14	60.1	682	665	97
15	61.6	689	666	97
16	62.2	689	669	98
17	61.9	685	666	98
18	61.1	686	668	97
19	61.6	686	666	97
20	61.0	685	668	97
21	62.2	686	667	97

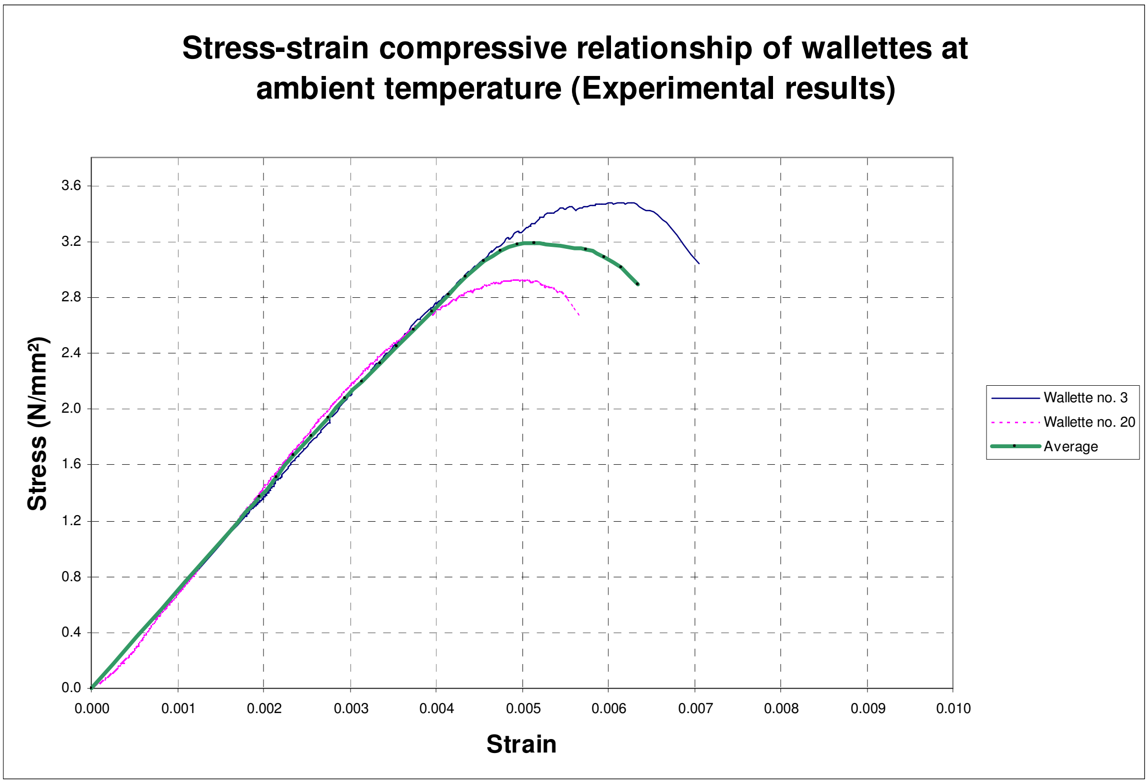


Figure 63: Stress-strain relationship of wallettes at ambient temperature.

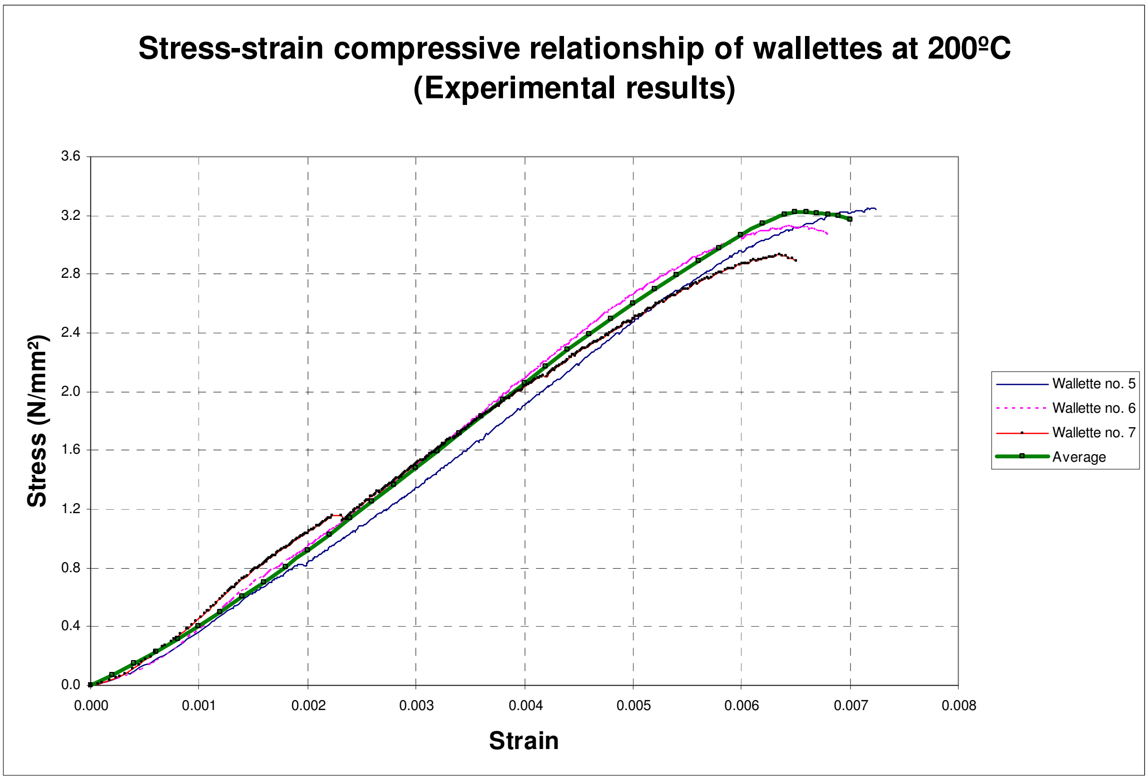


Figure 64: Stress-strain relationship of wallettes at 200ºC.

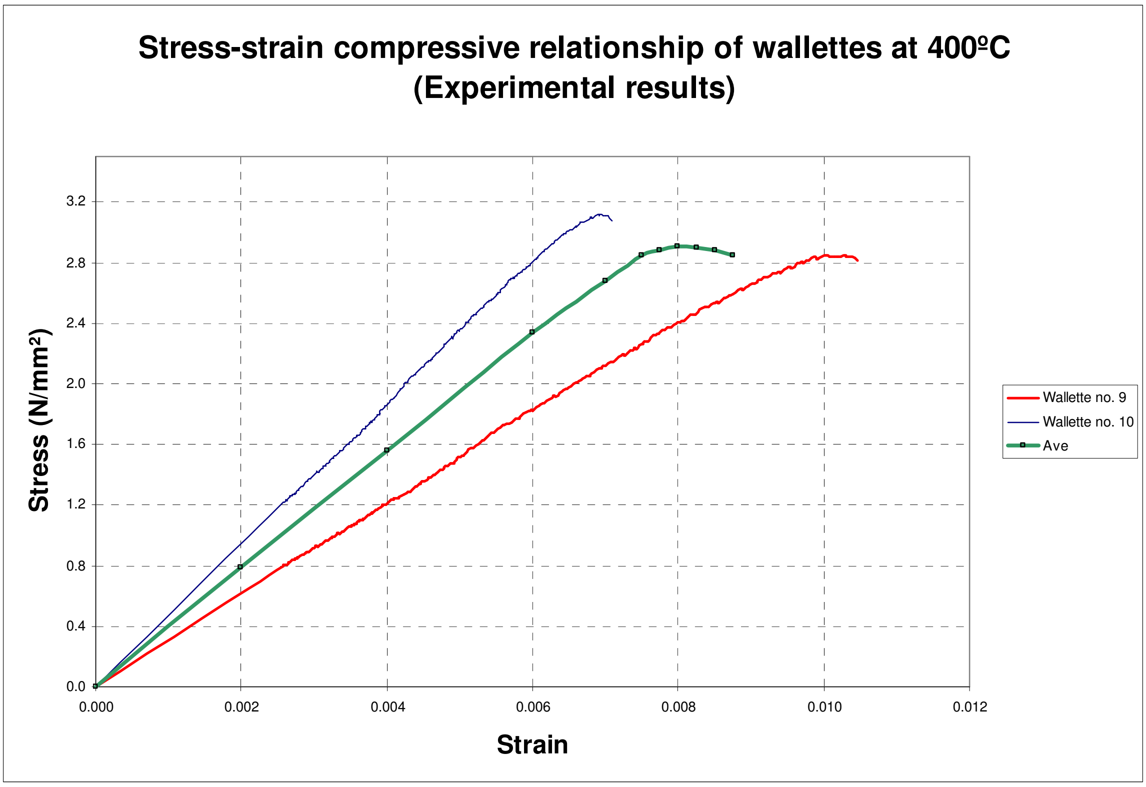


Figure 65: Stress-strain relationship of wallettes at 400ºC.

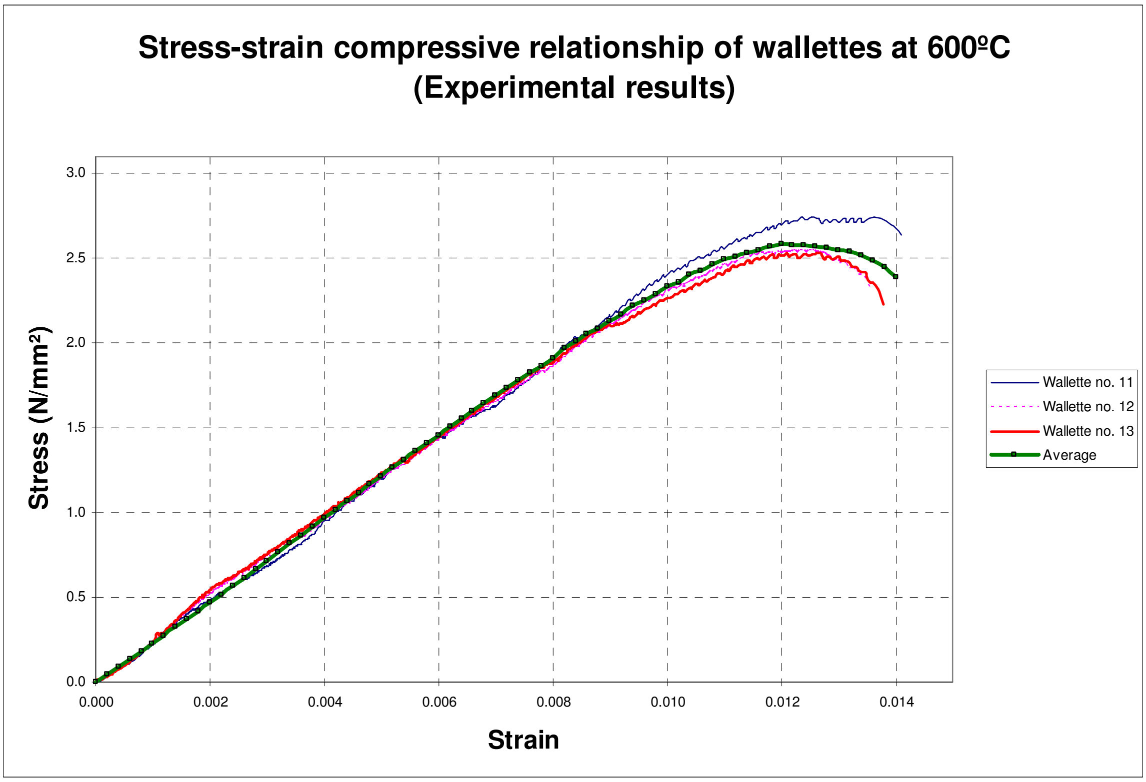


Figure 66: Stress-strain relationship of wallettes at 600ºC.

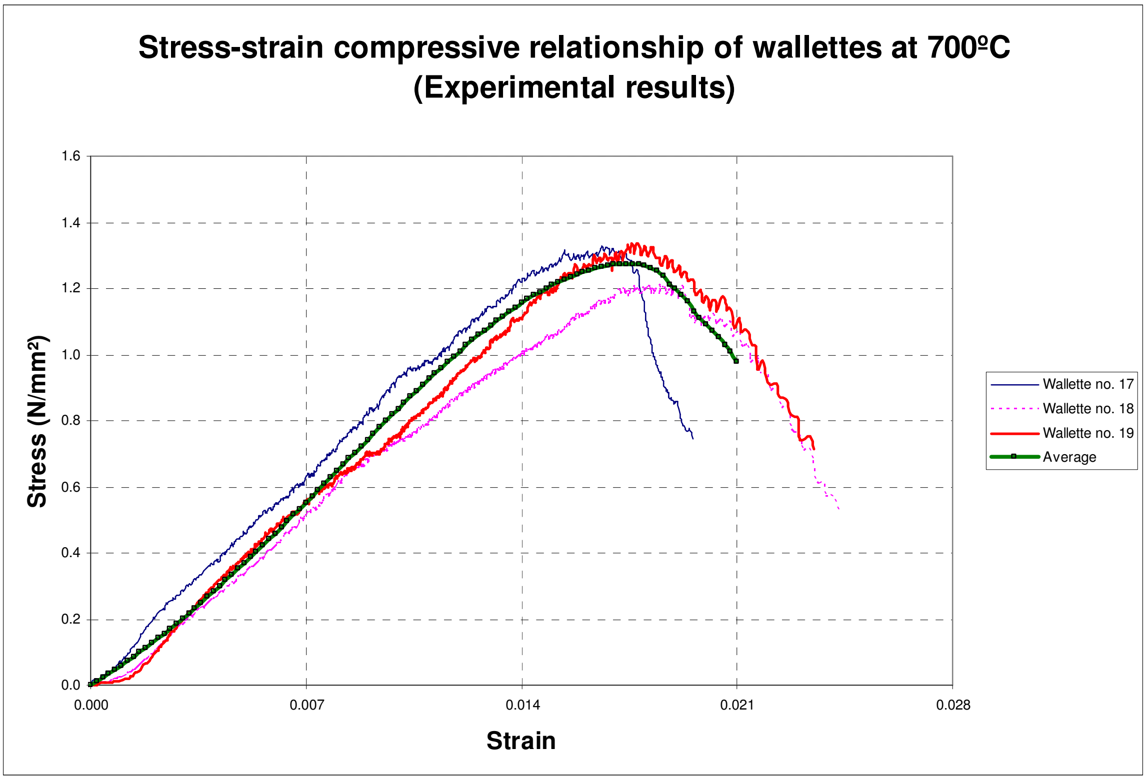


Figure 67: Stress-strain relationship of wallettes at 700ºC.

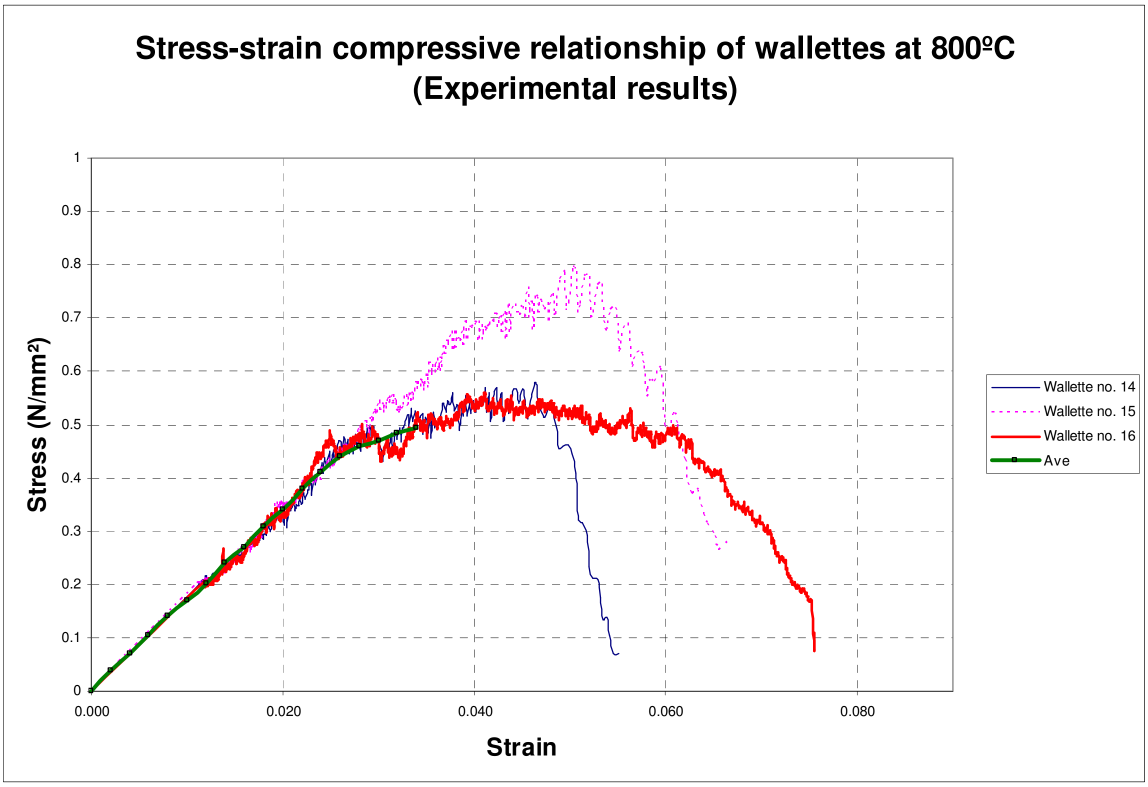


Figure 68: Stress-strain relationship of wallettes at 800ºC.

Figures 63 to 68 show the final stress-strain relationships of the masonry wallettes tested at different high temperatures. Initially load-deflection relationships were obtained from testing the wallettes in the laboratory and subsequently they were converted into stress-strain relationships by dividing the loads in the bearing area of the specimen and the corresponding deflection in the original height of the wallette (see Appendix B).

For the wallettes tested at ambient temperature, it can be observed that the average results from only two specimens were plotted. During the phase of unheated and heated wallette tests, it was experienced some erroneous reading caused by damage in the connecting part between the computer and the measuring devices. Due to this experience, the information obtained from some of these tests was rejected and consequently some specimens were not included in the final results of this work. The first wallette achieved a maximum stress of 3.48N/mm²; meanwhile, the second wallette had 2.92N/mm² as the ultimate stress.

The stress-strain relationship of three specimens tested at 200ºC was a second-degree parabola. However, based on the results shown in Figure 66 it can be appreciated that the stress-strain relationships were quasi-linear; the maximum stresses were 2.9N/mm², 3.1N/mm² and 3.3N/mm². In all the cases, the initial phase of the curve was characterized by a disruption presented at the range of 0-1.2N/mm²; this was associated with an imperfect parallelism between the faces of all the elements implicated in the loading system. To improve this situation, one loading cycle was applied for further tests; initially a wallette was loaded up to 10% of its expected maximum load and it was then unloaded to be finally crushed until failure occurred.

The average stress was 2.98N/mm² for the wallettes tested at 400ºC. This was another case in which one of the specimens could not be completed due to the failure in the used instrumentation. The average stress was therefore obtained from two wallettes.

From Figure 66, the stress-strain curves coming from wallettes heated and tested at 600ºC showed an almost ideal behaviour, where a quasi-linear performance approximately up to 2.2N/mm² was achieved and later a subsequent plastic region clearly formed.

The curves from the wallettes tested at 700ºC showed a continuous wavy performance, which was accredited to the formation of cracks and openings in the material at that temperature. But at the moment of being pressured by the compressive loads, these pores, cracks and openings were so compacted that irregular load and deflection readings were caused. The maximum stresses were 1.2N/mm², 1.33N/mm² and 1.38N/mm².

The highest temperature at which wallettes were exposed was 800ºC, whose results are shown in Figure 68. The three wallette curves showed the same behaviour as those from tests at 700ºC, but the wavy shape was even more marked in the curves of the wallettes tested at 800ºC due to the most severe damage at this temperature. The maximum stress for two wallettes was 0.54N/mm², whereas another wallette reached 0.8N/mm².

Figure 69 summarises the average stress-strain relationships of wallettes for all temperature groups. It can be observed that the curves from the specimens tested at 20ºC and 200ºC reflected a minor difference, which is practically nonexistent up to 1.5N/mm². According to these results, they could be grouped into three categories: the first can be considered up to 200ºC, in which the stresses are minimally reduced; the second group could be contained in the range of 200ºC-600ºC, at which the stress is moderately reduced; and finally the third group could be ranged between 600ºC and 800ºC, at this the stresses could be considered to be rapidly decreasing to minimum values.

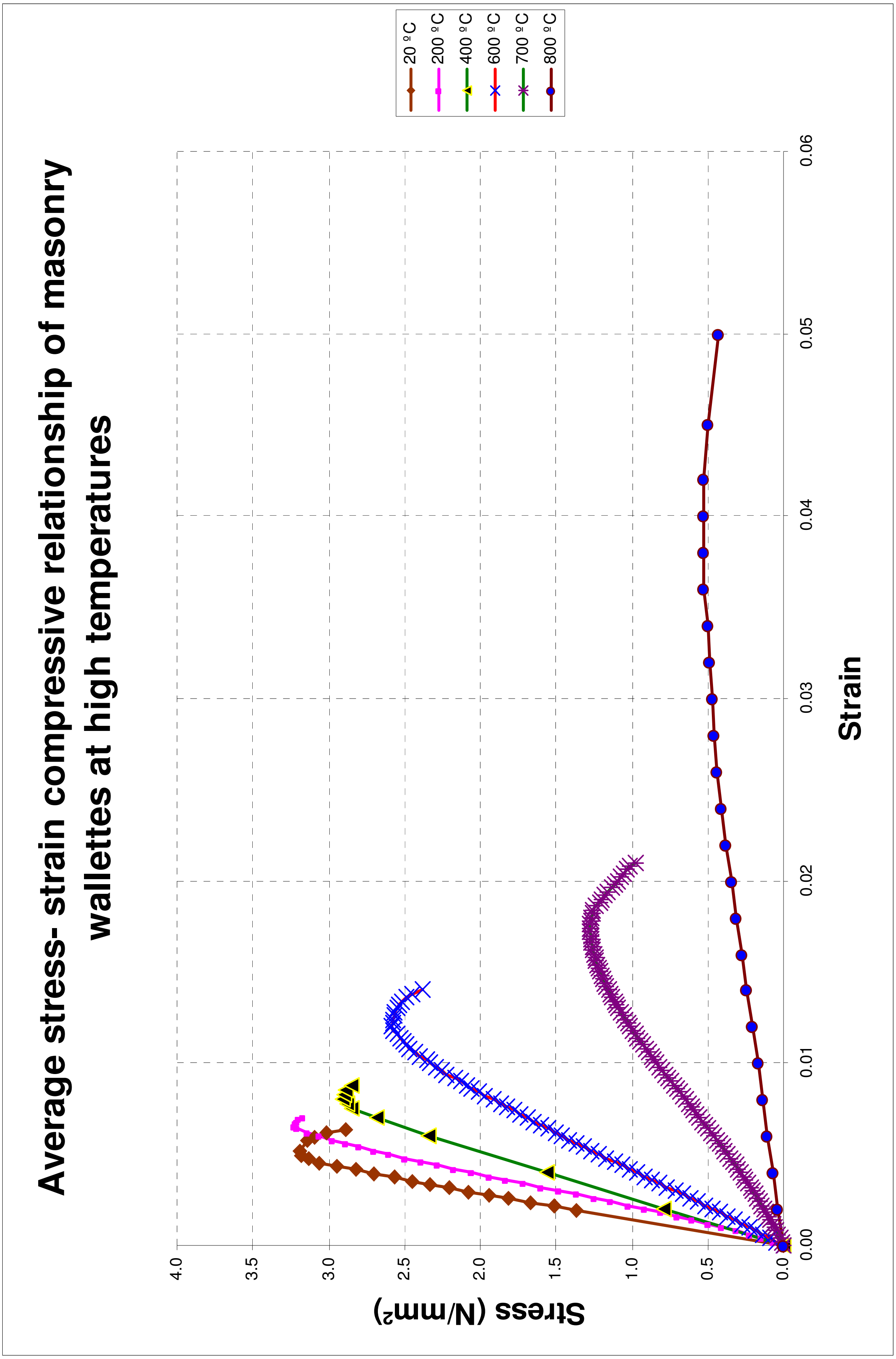


Figure 69: Stress-strain relationships of wallettes at elevated temperatures.

4.2.1.3 Reduced compressive strength

In this section the reduced compressive strength of the masonry wallettes in fire is presented. Figure 70 shows the final variation of the compressive strength. Each data point represents the average of the ultimate compressive strength of three masonry wallettes, in some cases from only two wallettes, normalized in accordance with the maximum compressive strength obtained at ambient temperature.

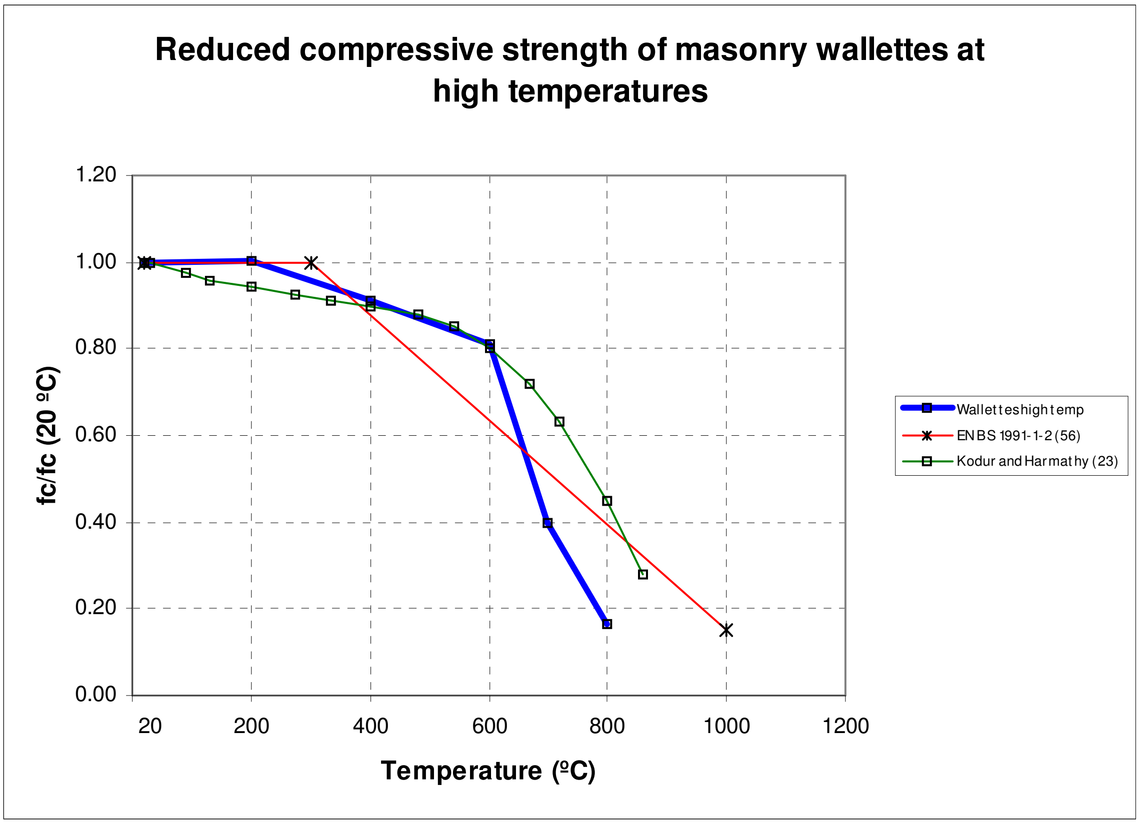


Figure 70: Reduced compressive strength of masonry wallettes at high temperatures.

The trend observed in this figure shows that the strength did not exhibit an important reduction at 200ºC, which was only 3%; at 400ºC the reduction was in the order of 9%; a higher decrease in the strength was at 600ºC with 19%; the compressive strength dropped to 60% when they were heated at 700ºC, finally the reduction of the strength was roughly 83% at 800ºC.

Among the models in the literature to validate masonry compressive strength, that from BS EN 1992-1-2 [56] exhibits a good agreement with the results from 20ºC to 400ºC and at 650ºC, over this temperature there is not good agreement.

The heated masonry model is also compared against results obtained by Kodur and Harmathy [23], which is based on unstressed conditions of a mixture containing lightweight aggregates and sand; the comparison is very similar from 20ºC up to 600ºC, above this temperature the comparison is not good.

Table 4.3 Experimental results.

Temperature (ºC)	Number of specimens	Average failure load (KN)	Average vertical deflection (mm)	Mean compressive strength (MPa)	Characteristic compressive strength f_k (MPa)
20	2	206.95	4.23	3.31	2.67
200	3	201.43	4.59	3.25	2.59
400	2	179.80	5.50	2.83	2.32
600	3	168.30	8.70	2.62	2.17
700	3	83.67	11.95	1.27	1.08
800	3	41.67	27.56	0.56	0.54

The most relevant results from the wallettes tested at elevated temperatures are shown in the Table 4.3. It indicates the number of specimens tested at each temperature. It can be observed that the difference between the failure loads at ambient and 200ºC is almost minimal. The loads decreased as the temperature increased from 207KN to 41.7KN at 800ºC.

Results confirmed that the vertical displacements increased with temperature as expected, the largest displacements can be seen at 800ºC which were around 27.6mm in comparison with those at lower temperatures. The mean compressive strength was obtained from the number of specimens indicated in the same table, the mean compressive strengths varied in the range of 3.31MPa to 0.56MPa.

The characteristic compressive strength was obtained based on the requisites in BS 1052-1 [86], which states that the characteristic compressive strength should be obtained from:

$$f_k = \frac{f}{1.2} \quad \text{or} \quad f_k = f_{i,\min} \tag{6}$$

Whichever is the smaller.

Where

f_k is the characteristic compressive strength of the masonry (N/mm²)

f is the mean compressive strength of the masonry (N/mm²)

f_i is the compressive strength of an individual masonry specimen (N/mm²)

The maximum characteristic compressive strength was 2.67MPa at room temperature, which decreased to 0.54MPa at 800ºC.

4.2.1.4 Reduced modulus of elasticity

The modulus of elasticity for masonry wallettes exposed to fire was evaluated from the same expression at BS EN 1052-1 [86].

$$E_i = \frac{F_{i\max}}{3 \cdot \in_i \cdot A_i} \tag{7}$$

Where:

E_i is the modulus of elasticity as a secant modulus from the mean of strains ($\in_i$) occurred at a stress equal to one third of the maximum stress reached.

$F_{i\max}$ is the maximum load applied on the wallette.

A_i is the bearing cross area of the wallette.

Table 4.4 Values of the modulus of elasticity from masonry wallettes in fire.

Temperature (ºC)	**Modulus of elasticity (MPa)**
	EN 1052-1 [86]
20	697
200	466
400	418
600	241
700	77
800	17

Table 4.4 shows the obtained moduli values, the apparent small modulus of elasticity values obtained were a result as a consequence of a higher volume percentage of the aggregates in the concrete wallettes, which differs from that in normal concrete. This has been reported to induce in much lower stiffness [114]. On the other hand, further studies on determining the reduced moduli proportion between lightweight and normal concretes has been conducted and has revealed that the stiffness of lightweight concrete is approximately 20% to 30% less than normal concrete [115].

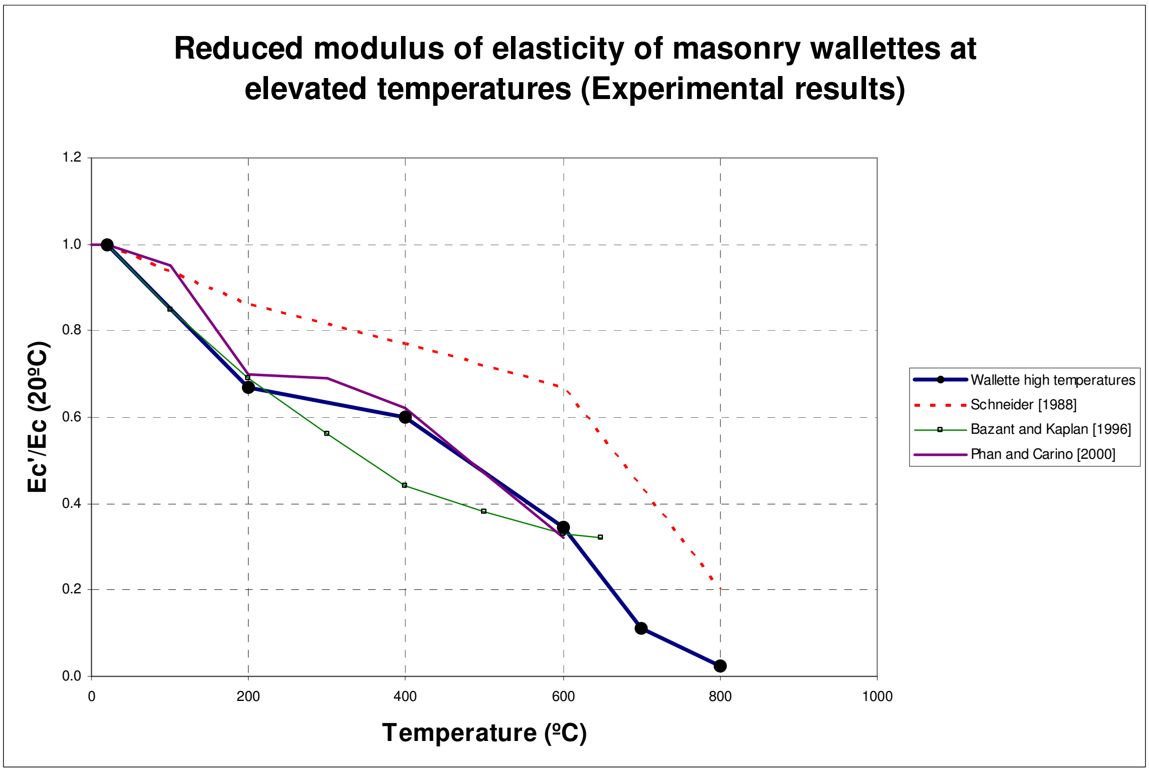


Figure 71: Reduced modulus of elasticity of wallettes at elevated temperatures.

Figure 71 shows the normalized modulus of elasticity from the masonry wallettes tested at elevated temperatures. The reduced modulus was normalized from the maximum moduli obtained at room temperature. It can be seen that there was a reduction of 33% at 200ºC, a more considerable reduction at 400ºC of approximately 40%; at 600ºC moduli decline was 65%; the modulus dropped until 11% of its original value at 700ºC; the deterioration in Young's modulus was 2% of its original value at 800ºC. The reduced modulus is compared with other similar results which are generally in good agreement but not with that obtained by Schneider [33].

4.2.1.5 Failure modes

This segment deals with the failure modes which occurred in the masonry wallettes under heated compressive tests.

At 20ºC, two specimens were only tested successfully. One of them showed a conical shear compressive failure as the dominant feature. This type of failure is associated with specimens having low slenderness ratios and with the effects of bearing plate thickness; it has been demonstrated that bearing plates with sufficient thickness can reduce bending effects [29]. The second wallette failed due to development of a crack, which formed a wedge at the bottom of the specimen. This wedge induced separation of the specimen resulting in failure, sometimes this wedge causes a severe crushing of the blocks [84]; these failures are shown in Figure 72.

Figure 72: Failure modes of wallettes tested at ambient temperature.

The wallettes tested at 200ºC had different failure patterns (see Figure 73); the first wallette repeated the same type of conical failure occurring in the first wallette as previously discussed; the second specimen had a similar failure due to the eventual formation of a wedge at the bottom. The last specimen failed owing to shear across an inclined plane through the blocks; this type of failure has been related to cases where the blocks are weaker than the mortar; the mortar experiences a bilateral compressive restraint on the blocks which are consequently in a state of triaxial compression [84].

Figure 73: Failure modes of wallettes tested at 200ºC.

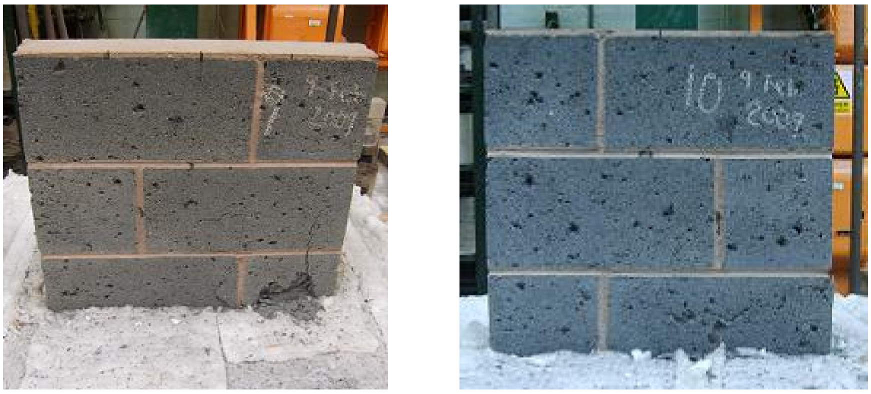


Figure 74: Failure modes of wallettes tested at 400ºC.

When the specimens were heated at 400ºC, significant heat damage resulted. Initially the wallettes were affected by spalling at this temperature, leading to more rapid cracks and openings, which subsequently propagated the formation of wedges and cracking at the bottom of the specimens and the consequent failure of the specimens. This is another case in which was demonstrated that the blocks were weaker than the mortar.

Figure 75: Failure modes of wallettes tested at 600ºC.

For the wallettes tested at 600ºC a continuous type of failure occurred. It was observed that as increasing the temperature, the spalling was more severe. The failure in this group of specimens was characterized by the rupture of the wallette faces causing their separation due to splitting. This type of failure is often attributed to transversal tensile stresses which usually cause the blocks and the mortar to disintegrate [84]. A number of striking vertical cracks can also be observed (see Figure 75).

The wallettes, tested at 700ºC, failed, owing to a combination of different factors. All of them had a failure pattern characterized by shear across an inclined plane through the blocks, but they also showed severe damage due to spalling causing multiple external openings and cracks, which could have influenced the failure. Finally, the wallettes exhibited expansion as result of the high temperature effects (see Figure 76).

Figure 76: Failure modes of wallettes tested at 700ºC.

Complete material degradation at 800ºC was observed to be the most important feature for these wallettes. In Figure 77 it can be seen that the material was completely degraded and clearly showed a vertical lateral curvature, this was accompanied by the typical shear failure formed along the inclined plane through the blocks. It can also be noted that the wallettes were seriously damaged by the type of spalling typical of this material. In addition, vertical cracking occurred starting at the mortar corners and further extending into the blocks.

Figure 77: Failure modes of wallettes tested at 800ºC.

4.2.1.6 Spalling

As demonstrated in the majority of the figures shown previously, spalling occurred in the wallettes tested at and over 400ºC. According to the evidence presented by the wallettes after being heated, this type of spalling is identified as "aggregate splitting" or "surface pitting". The spalling features obtained from the masonry tests are summarized as follows:

- Small aggregate pieces, of approximately less than 20mm, were flying off the surface of the masonry wallettes.
- This type of spalling has been identified by a sound similar to that of pop corn, which happened during these tests and was heard after 26min in the wallettes tested at 400ºC and 600ºC, but this changed for tests with target temperatures of 700ºC and 800ºC with the sound being heard after approximately 30min.
- After the first spalled piece was heard, subsequent pieces spalled with the same intensity and frequency until the end of the compressive test.
- By visual judgment, it can be observed that spalling caused the same level of damage in all the wallettes. However, some cracking sounds were also heard during some tests mainly at 700ºC and 800ºC.

Although spalling is still an unpredictable phenomenon, being complex to display the exactly parameters involved, this is generally associated with a combined action of pore pressure produced by moisture evaporation and high internal stresses resulting from the expansion of the hot material against its surroundings including adjacent cooler concrete or initial loading [116]. Therefore, spalling is considered as dependent on the aggregate type, more than 5% (by volume) of moisture content [92], stress level, heating rate, target temperatures, and other parameters.

On the other hand, if violent spalling had occurred, the masonry compressive tests could not have been completed. It can be assumed that violent spalling can occur when the magnitude of internal stresses caused by vapour pressure is not the same as that for normal concrete. In part, this has been related to the greater porosity of lightweight aggregate particles allowing the dissipation of vapour pressure. Lightweight aggregates can then absorb much water or vapour and spalling can occur as a function of the space in which the vapour is enclosed, the distance to the surface of the member, the tensile strength of the concrete and the vapour pressure [117,118].

4.2.1.7 Material Degradation

In this section, the most important aspects related to fire behaviour of the masonry materials are highlighted.

4.2.1.7.1 Change of colour

Although this was not one of the main objectives of this research, owing to the lack of appropriate equipment and the fact that this is not considered to be a primary fire effect, this explanation describes the possible main factors that could have caused the change of colour in the masonry wallettes.

All the specimens tested at high temperatures experienced a change of colour, which was less apparent in those specimens tested at 200ºC and 400ºC and more obvious for the tests carried out at 600ºC, 700ºC and 800ºC. The different levels of colour in the wallettes can be appreciated in the Figures 72 to 77 shown previously.

Due to an inconsistence of colour change, it is necessary to consider changes in mortar separately from that exhibited by the lightweight concrete blocks. It was observed that the change of colour in mortar was almost imperceptible at 200ºC; from this temperature, the iron contained in most sands used for building mortar has been reported to play a crucial role [128,129], since the fire damage leads to chemical reaction altering the colour from light pink-grey at room temperature to only slight pink colour at 200ºC. At 400ºC the mortar was a more intense pink colour; but this appearance was much more distinctive at 600ºC, in fact, the colour was markedly reddish. However, at 700ºC the mortar experienced a complete colour loss; it was similar to the mortar colour at ambient temperature. Finally, the mortar was a greyish white at 800ºC.

With the colour changes for the blocks in the wallettes there was no important change in the specimens tested at ambient and at 200ºC. Initially the wallettes had a dark grey colour which was maintained after being heated at 200ºC and even up to 400ºC. Significant changes occurred in those wallettes tested at 600ºC, whose external shade changed to a uniform light grey. However, it is worth mentioning that after some tests were finished it was observed that some block pieces showed the original dark grey colour in their interior (see Figure 78), which is assumed to be due to an imperfect heating phase.

Figure 78: Change of colour in the wallettes tested at 600ºC.

At 700ºC, the colour of the blocks was a slightly lighter grey than that of the blocks tested at 600ºC. Finally, blocks in the wallettes heated and tested at 800ºC became almost white. The results, obtained from this research, coincide with the investigations carried out on determining the expected colours (pink or red) of heated concrete. This also matches the studies on demonstrating colour intensity due to the type of aggregates, target temperatures and duration of heating [130,132].

4.2.1.7.2 Melting of aggregate particles

After the wallettes were tested and most markedly at 700ºC and 800ºC, it was observed that a number of lightweight aggregate particles were melted. This phase-change (from solid to liquid and again to solid when cooled) was the result of an increase in the internal energy of some lightweight aggregates at those temperatures.

Figure 79: Melting of lightweight aggregates at 700ºC and 800ºC.

The fusion of these lightweight aggregate particles was then achieved when the wallettes were heated at 700ºC and 800ºC and these temperatures exceeded the aggregate melting point that is a state at which the molecular entities of the aggregates can control their ability of vibrating which in turn causes the break down of solids [123].

4.2.2 Blocks

In order to complement the study of the fire performance of masonry wallettes, a specified number of lightweight concrete blocks were tested under identical thermal conditions to those used for the wallettes. The results highlight the stress-strain relationships of the blocks with temperature, which is the required data to be incorporated for the finite element models developed to simulate masonry walls in fire; the reduced modulus of elasticity, failure modes and heat damaged material features are also presented.

4.2.2.1 Thermal performance

The thermal behaviour of the lightweight concrete blocks, in terms of the temperature evolution with time, is shown in this section. In general, six masonry units were tested at 20º, 200ºC, 400ºC, 600ºC and 800ºC to determine the compressive strength as prescribed in reference [110] and explained in the Chapter 3. The blocks were subjected to steady state conditions, similar to the test method used for the wallettes.

As observed in Figure 80, four curves were plotted showing the temperature-time relationships for the blocks tested at different high temperatures. One curve shows the temperature inside the block, it is denoted as “Internal block temp”; “Surface temp” indicates the average temperature from two thermocouples attached in the surface of the block; two thermocouples were placed to measure the temperature inside the furnace, they are denoted as “Furnace temp1 and Furnace temp2”.

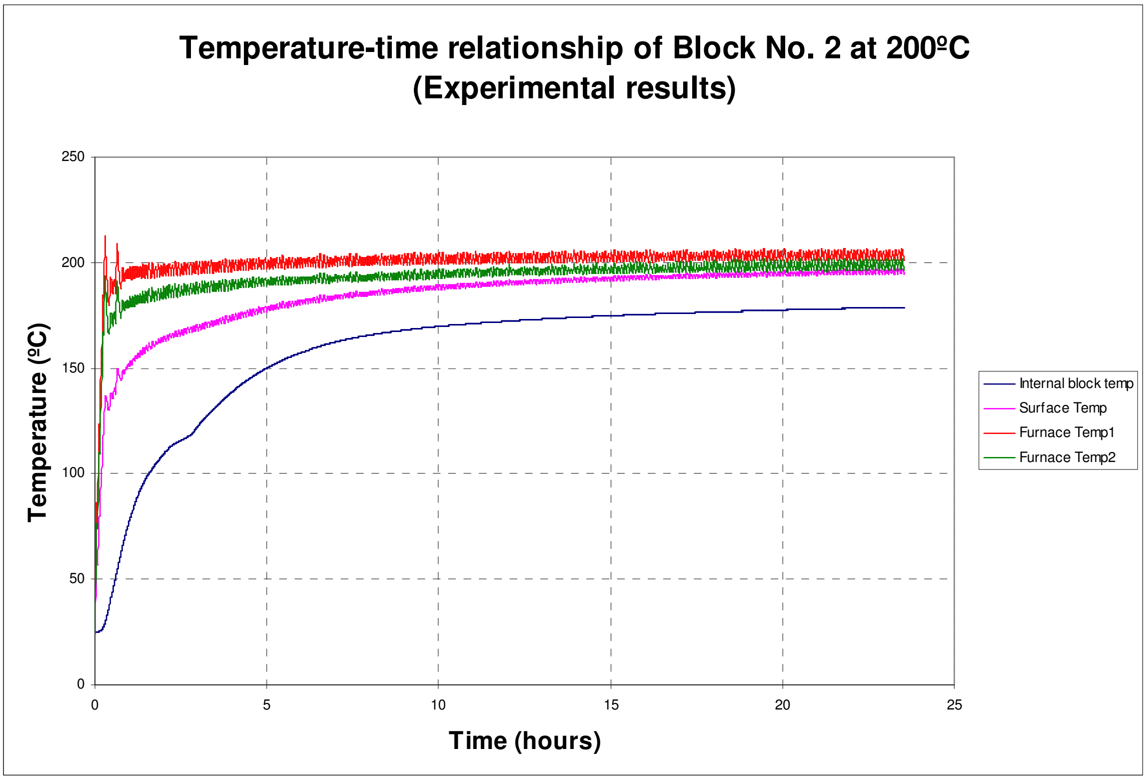


Figure 80: Temperature-time relationship of LW block at 200ºC.

In the blocks heated at 200ºC, the thermal balance was not achieved. This was principally assumed to be due to the method of insulating. At the beginning of these tests, two 25mm thick layers of insulating blankets were employed to protect the bottom steel plate, whose function was to support the specimens and the furnace, against the effects of the high temperatures. However, the block area in direct contact with the blanket was not heated with the same intensity as the other areas, inducing an apparent temperature distribution as shown in Figure 81a.

During the heating phase, both the bottom and top faces of the unit were not directly heated because of the respective supports; for that reason, it is presumed that they induced a colder state in the inner bottom blocks (reduced unshaded region in the Fig 81a) for indeterminate time and consequently this reduced the heat transfer. This could explain the longer times taken in the tests at 200ºC, for which duration of 24hrs was recorded.

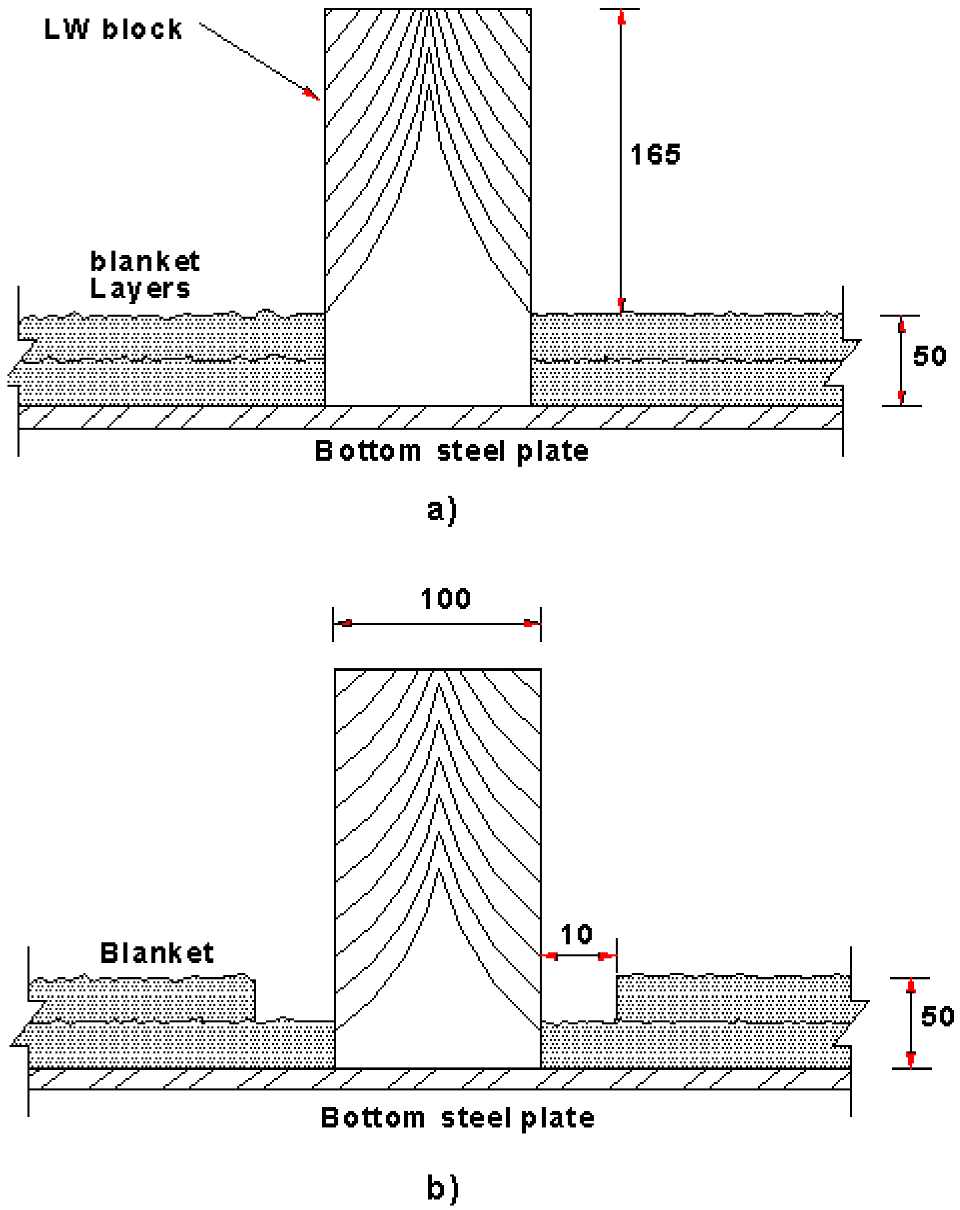


Figure 81: Block tests at 200ºC.

For subsequent block tests, some modifications in the isolation were attempted (see Figure 81b). The superior blanket layer was cut to reveal an approximately 10cm gap around the block to allow more area to be exposed at the same temperature and consequently to improve the temperature distribution in the block. Thus, the thermal equilibrium was achieved for further tests as demonstrated in later graphs.

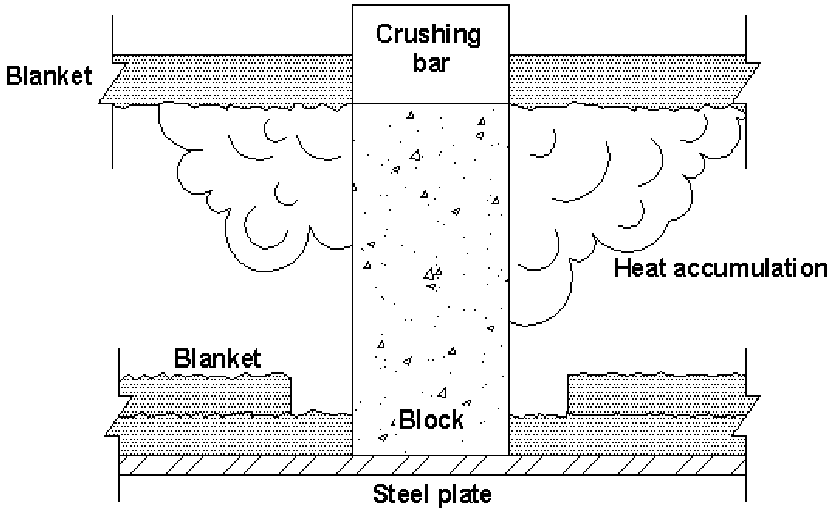


Figure 82: Heat distribution in the block tests at elevated temperatures.

It is also hypothesized that the accumulation of heat, as illustrated in Figure 82, influenced the fire performance of the blocks. As demonstrated in simulating a two-zone fire compartment model by using gas temperature [16], it is presumed that the gas products (mass, energy and chemical substances) are naturally emitted to upper layers; similar conditions are considered to have occurred in the blocks but heated with an electric furnace. Heat accumulation is then speculated to concentrate more in the upper layers than in the lower ones of the furnace and to affect the fire performance of the blocks.

With hotter temperatures at the top of the furnace, it is thought that the blocks were more damaged in their upper parts than in the lower, this stage was maintained for the total duration of the test. Moreover, although the temperature inside the furnace was registered to be uniform after a time, the damage caused by that heat accumulation was considered relevant during the total duration of this phase.

On the other hand, in the case of the blocks heated at 200ºC, once the curve (to measure the temperature inside the block) exhibited an apparent horizontal shape around 170ºC and with the very long predicted test duration, the author decided to finish the heating phase and to start the application of the loads for determining the compressive strength at this temperature. Therefore, the blocks expected to be heated at 200ºC were really tested at 180ºC.

As occurred in the wallettes tested at 200ºC, the curve measuring the temperature from the block's interior was also disrupted by a plateau, which became visible at approximately 110ºC and lasted roughly 55min.

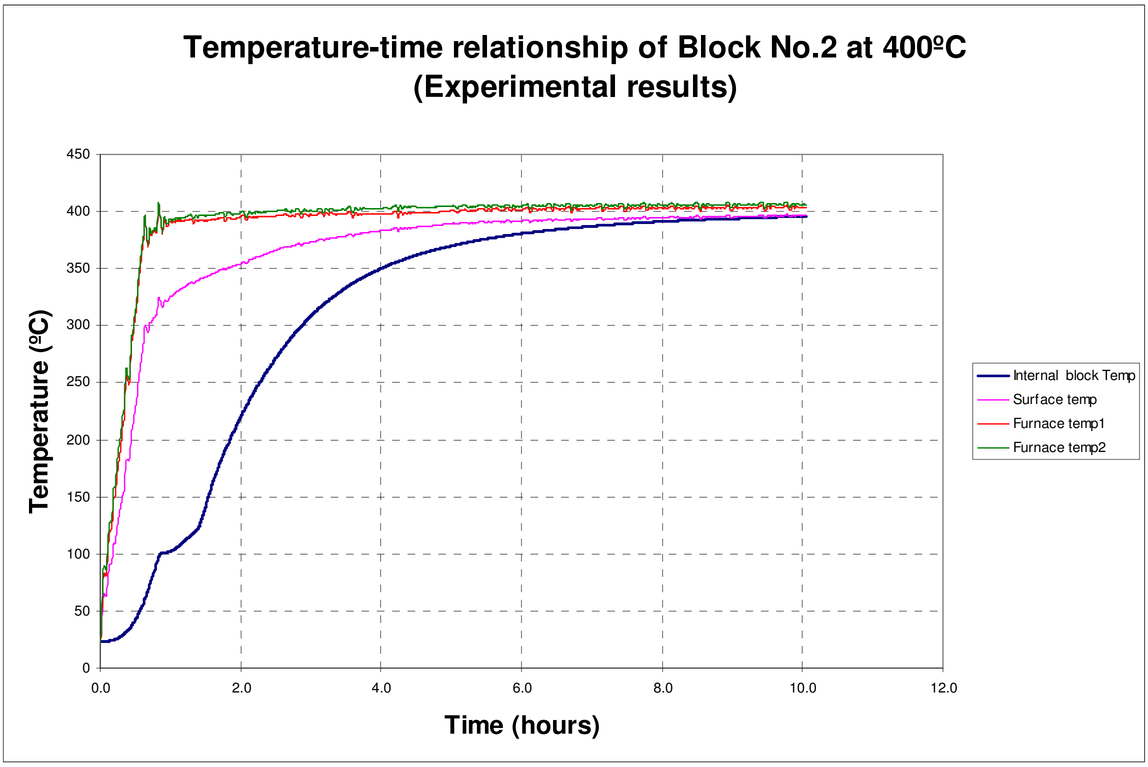


Figure 83: Temperature-time relationship of LW block at 400ºC.

At 400ºC, the thermal equilibrium occurred after approximately 10hrs (see Figure 83). The mean duration for plateau in those blocks was around 34min.

A typical temperature-time relationship of the blocks tested at 600ºC is shown in Figure 84. The average length for which the thermal balance was reached was in the order of 8hr to 10hr. Meanwhile, the mean duration for plateau was approximately 20min.

Figure 85 illustrates the evolution of the temperature from the positions at which type K thermocouples were located for the blocks heated at 800ºC. It can be observed that the curve recording the temperature of the furnace in the block joined suddenly to those curves that measured the temperature inside the furnace, at approximately 500ºC. This behaviour is due to the separation of the thermocouple attached to the surface of the block.

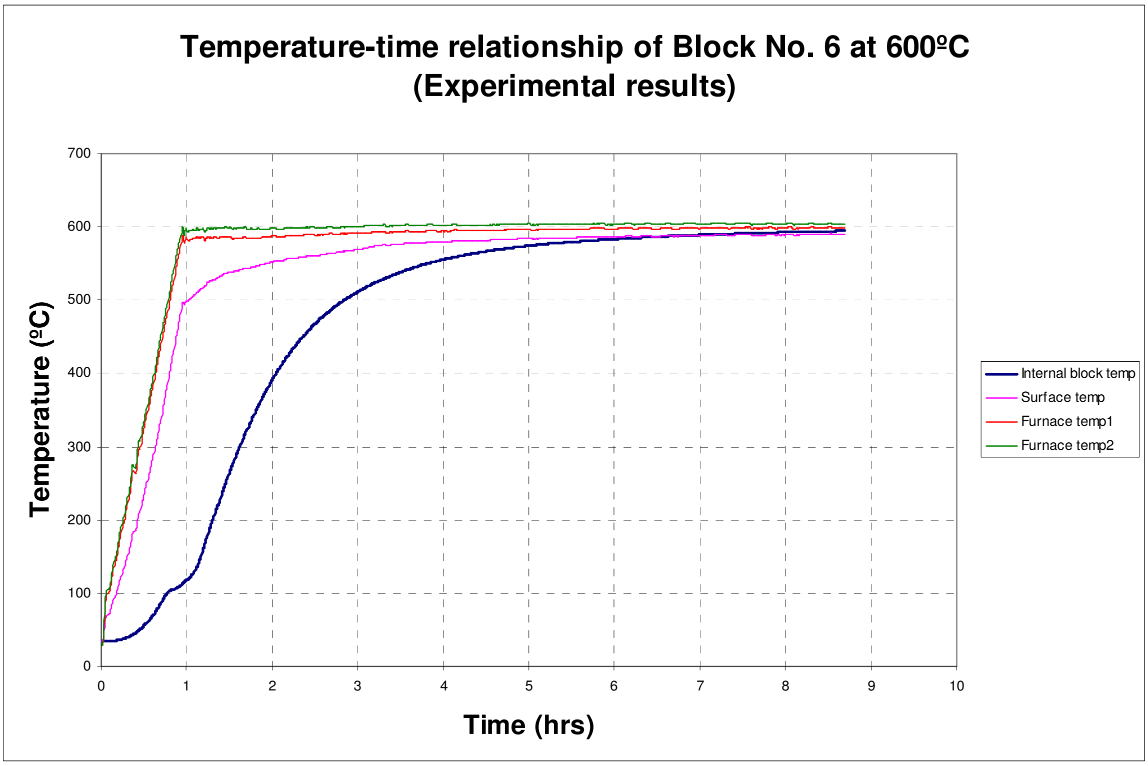


Figure 84: Temperature-time relationship of LW block at 600ºC.

In these tests, the thermal equilibrium was reached in around 9hrs. It is also observed that the characteristic plateau period appeared in the region near to 117ºC, whose duration was in the order of 20min.

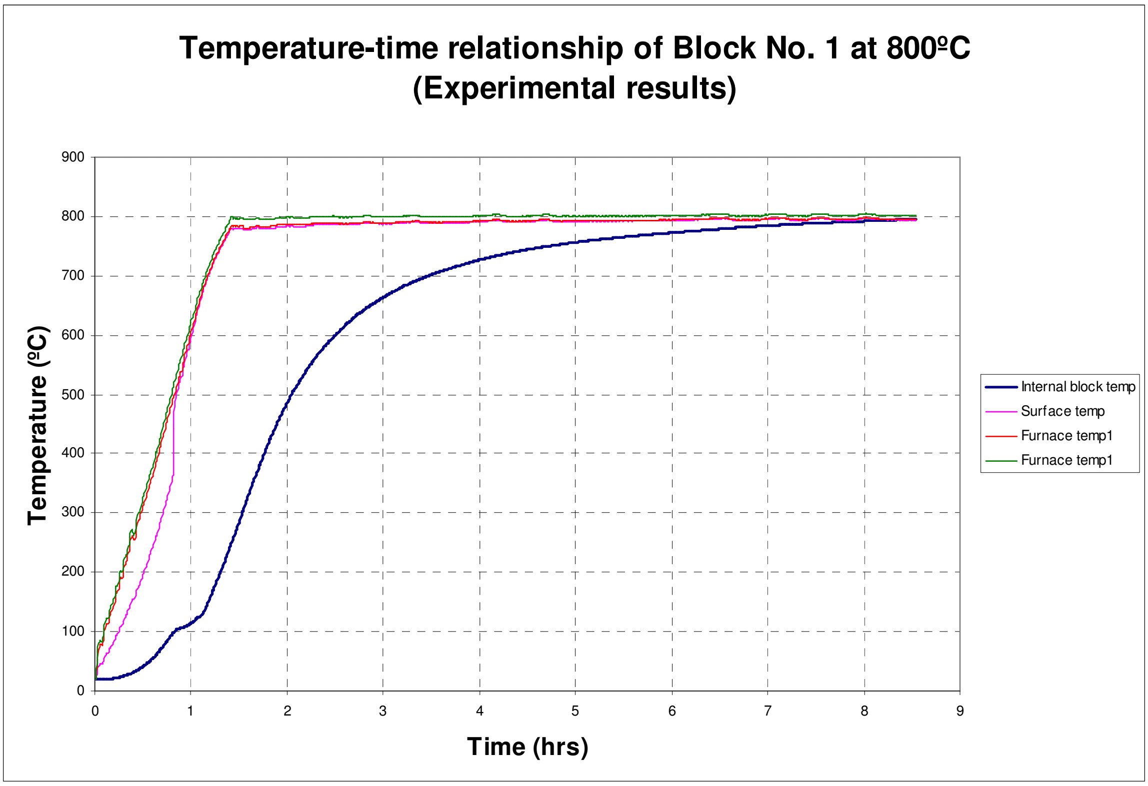


Figure 85: Temperature-time relationship of LW block at 800ºC.

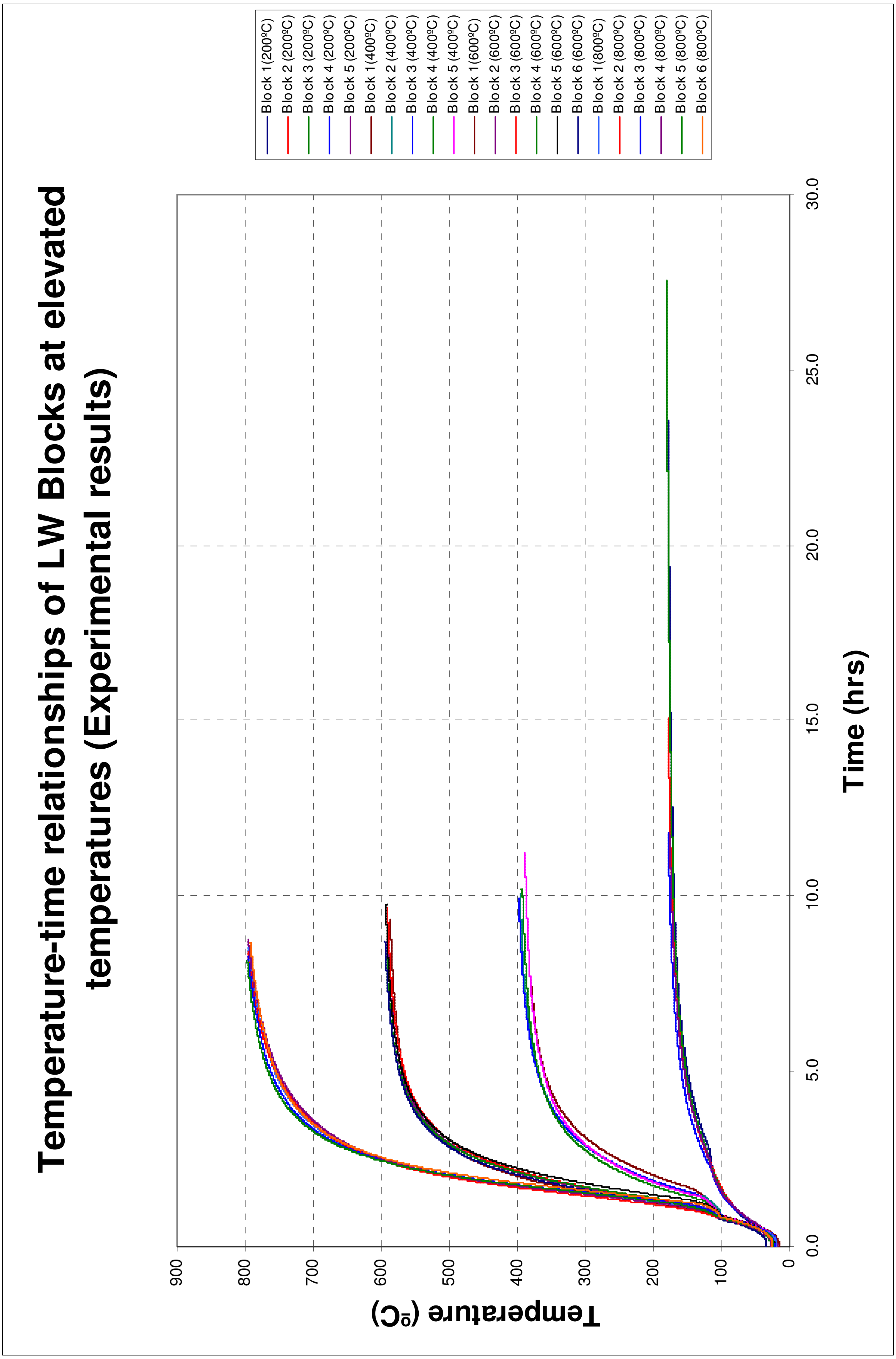


Figure 86: Temperature-time relationships of LW blocks at high temperatures.

A summary of the temperature-time relationships of the total blocks tested at different elevated temperatures is shown in Figure 86. It can be seen that the results from testing six blocks were plotted; however, five blocks were only plotted for the tests at 200ºC and 400ºC because one test failed due to an error in the instrumentation used for measuring deflections.

Moreover, longer durations can be observed in the tests at 200ºC, which contrasts with the shorter durations of the others at higher temperatures. In addition, the plateau was generally concentrated close to 115ºC.

4.2.2.2 Stress strain relationship

The compressive stress-strain relationships of lightweight concrete blocks obtained at different temperatures are shown in this section. The same procedure used for the stress-strain curves in the wallettes was applied to define the curves for the blocks since load-deflection (see Appendix C) relationships were initially obtained from the experimental results.

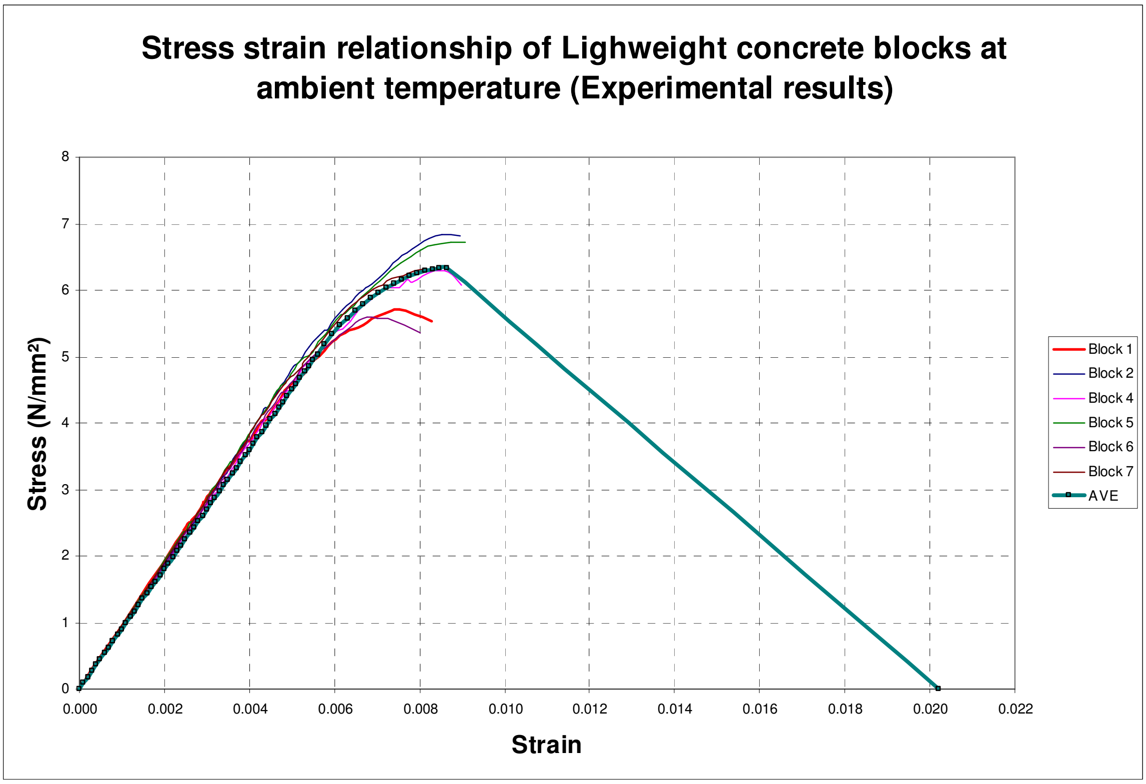


Figure 87: Stress-strain relationship of LW concrete blocks at ambient temperature.

It is appreciated, in Figure 87, that the stress strain relationships of the six blocks at ambient temperature were dominated by a well defined parabola with a markedly linear comportment up to approximately 5N/mm². The average maximum stress was 6.28N/mm².

Each curve is the average of two data points obtained directly from the tests; those data points come from the linear potentiometers located to measure the vertical deflections in the blocks. The resulting stress-strain curves from the blocks experimented at 200ºC can be seen in Figure 88. The maximum stress varied from 4.08N/mm² to 5.43N/mm². The mean maximum stress and strain were 4.58N/mm² and 0.009984 respectively.

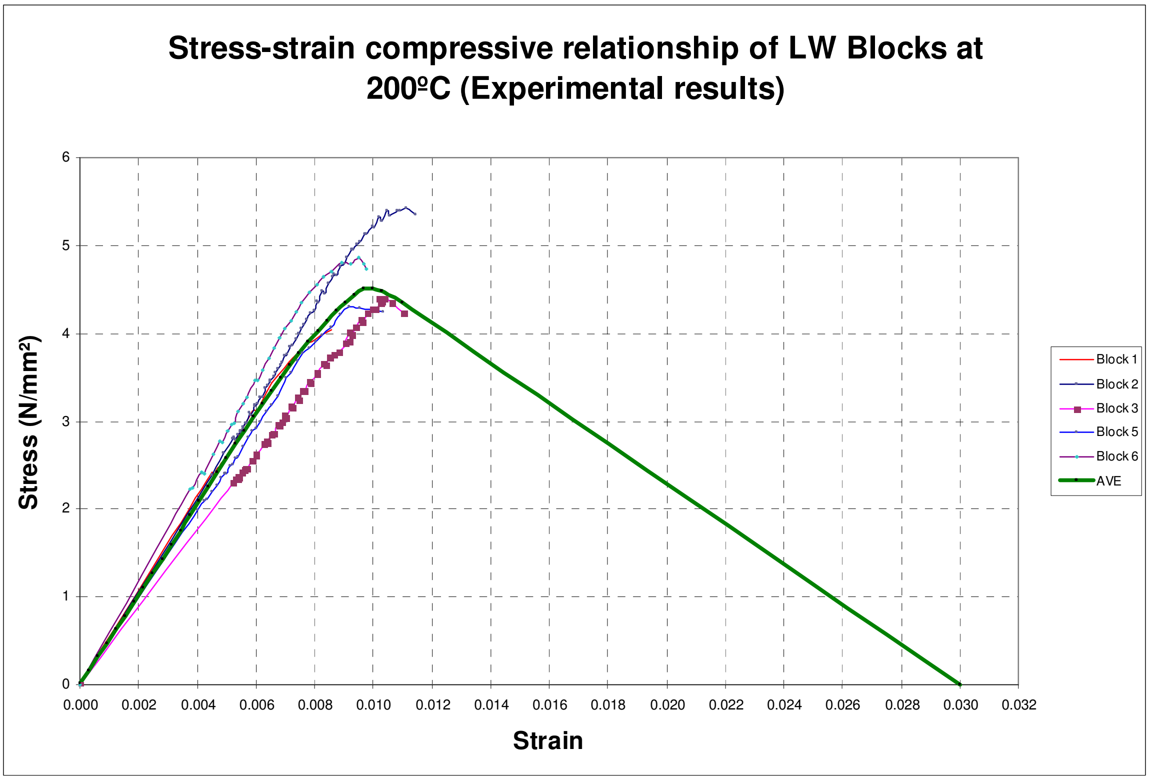


Figure 88: Stress-strain relationship of LW concrete blocks at 200ºC.

At 400ºC, the results were characterized by a concentration of all the curves in the range of 4.3N/mm² to 5.14N/mm². However, an unpredicted stress-strain curve (from block 3) affected this concentration and induced an average curve of 4.63N/mm². This unexpected behaviour in this block is attributed to some friction between the plates in the loading system that could have caused some eccentricities causing a premature failure and a lower strength compared to the rest.

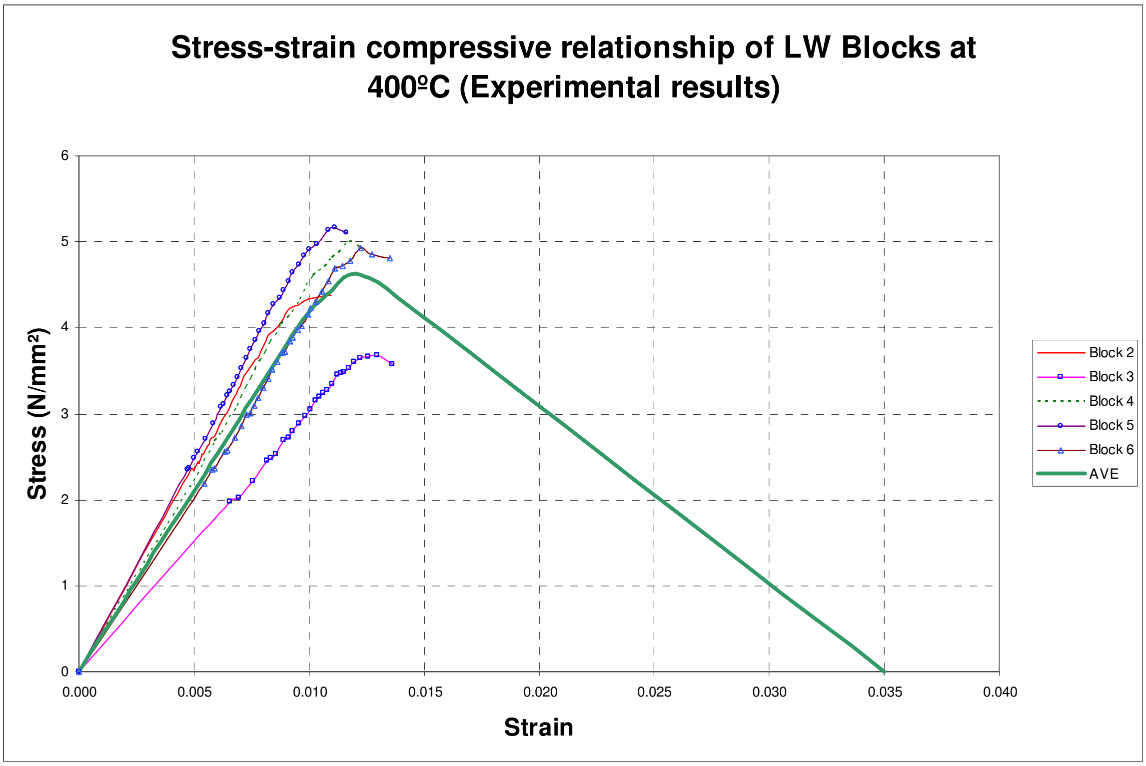


Figure 89: Stress-strain relationship of LW concrete blocks at 400ºC.

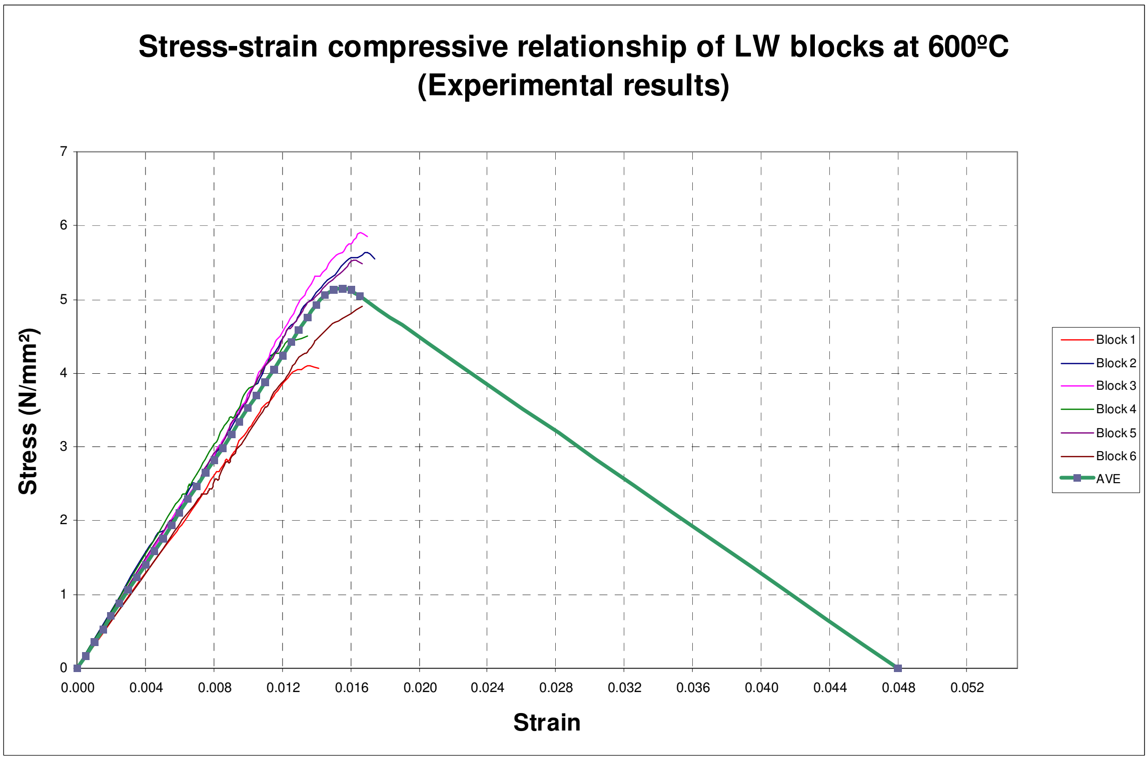


Figure 90: Stress-strain relationship of LW concrete blocks at 600ºC.

Unexpected maximum stresses were reached in some blocks tested at 600ºC, whose values were even greater than stresses obtained from some blocks tested at lower temperatures. As observed in Figure 90, the trend for all the curves was to define a typical non-linear shape. The greatest stress was 5.90N/mm² and a strain of 0.016550, the lowest stress was 4.1N/mm² with a corresponding strain 0.013641. The mean curve was distinguished by a stress of 5.14N/mm²; the consequential strain was in the order of 0.015.

Figure 91 shows the stress-strain compressive relationship of the blocks tested at 800ºC; these results demonstrated a distortion in the shape of the curves, although there was a good linear behaviour until approximately 1.50N/mm². The appearance of wavy points in the curves coincides with some audible cracks heard by the author during the application of the compressive loads.

At an approximate strain value of 0.025, most of the blocks had a markedly descendant point in the curve, which appeared at roughly 1.5N/mm², 2.0N/mm² and 2.4N/mm². These points are assumed to occur at the moment of the initial shear crack in the blocks.

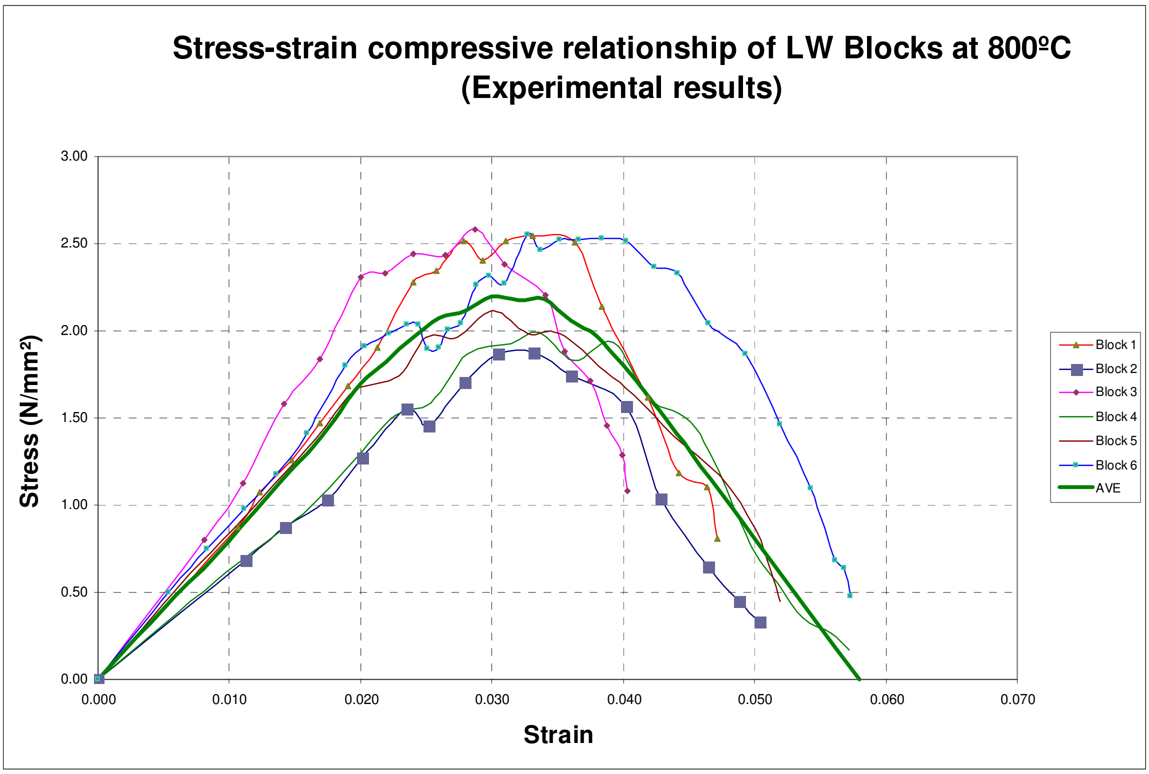


Figure 91: Stress-strain relationship of LW concrete blocks at 800ºC.

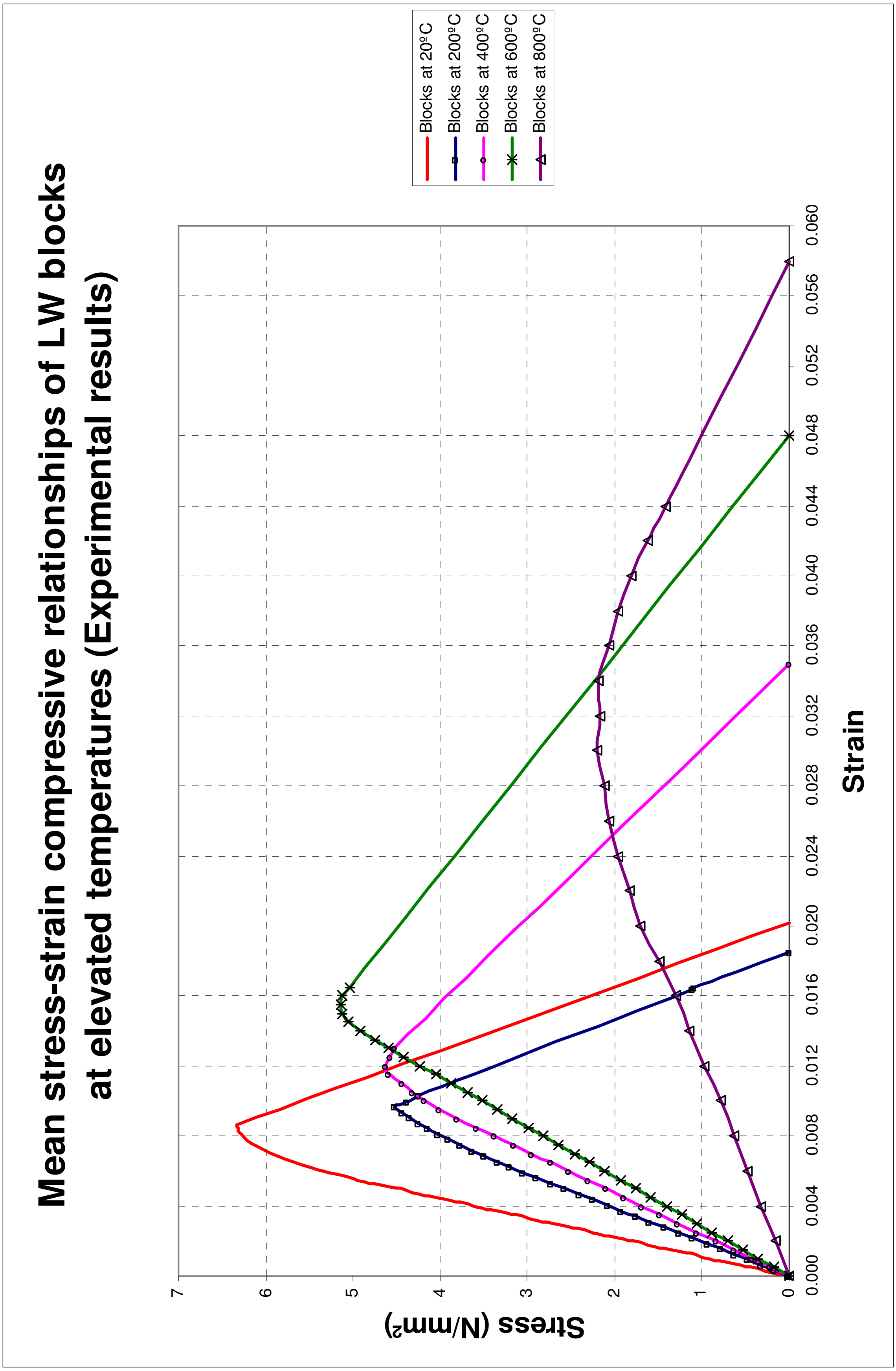


Figure 92: Stress-strain relationships of LW concrete blocks at high temperatures.

Figure 92 presents all the curves from the blocks tested at 20ºC, 200ºC, 400ºC, 600ºC and 800ºC, which was one of the objectives of this research. They depict the average from at least five blocks heated and tested at steady state conditions. The individual blocks were subjected to the same conditions used for the wallettes to compare their study and to use this information in the development of computer models. The significant difference between the curves at ambient temperature and those at higher temperatures is clearly observable. It is also interesting to appreciate the minor variation among the compressive relationships at 200ºC, 400ºC and 600ºC. Eventually, the curve showing the stress-strain relationship from the blocks tested at 800ºC dropped down to a maximum stress of 2.55N/mm², the corresponding strain was larger, as expected, in comparison with the others at lower temperatures.

4.2.2.3 Reduced compressive strength

The scope of this section is to display the experimental results based on the reduced compressive strength of the lightweight concrete blocks with temperature. Figure 93 shows the average loads at which the blocks failed. It can be seen that the loads were in the order of 267KN at ambient temperature. The mean loads were significantly decreased to 197KN at 200ºC. It is also interesting to note that between 200ºC and 600ºC the loads had an unpredicted behaviour, which was marked by an increase of the load as the temperature rose. However, the loads were abruptly reduced at 800ºC.

The reduced compressive strength of the blocks tested at elevated temperatures can be seen in Figure 94. The compressive strength was normalized from that obtained at 20ºC. It can be observed that the strength was reduced to approximately 28% at 200ºC and this reduction was almost the same at 400ºC at which a variation of 27% was reached. As observed at 600ºC, the reduction was about 18%. Finally, at 800ºC the reduction of the strength was 65%. This could be attributed to the excellent performance of the lightweight particle properties of the blocks at this temperature in comparison with blocks made of dense concrete or other materials.

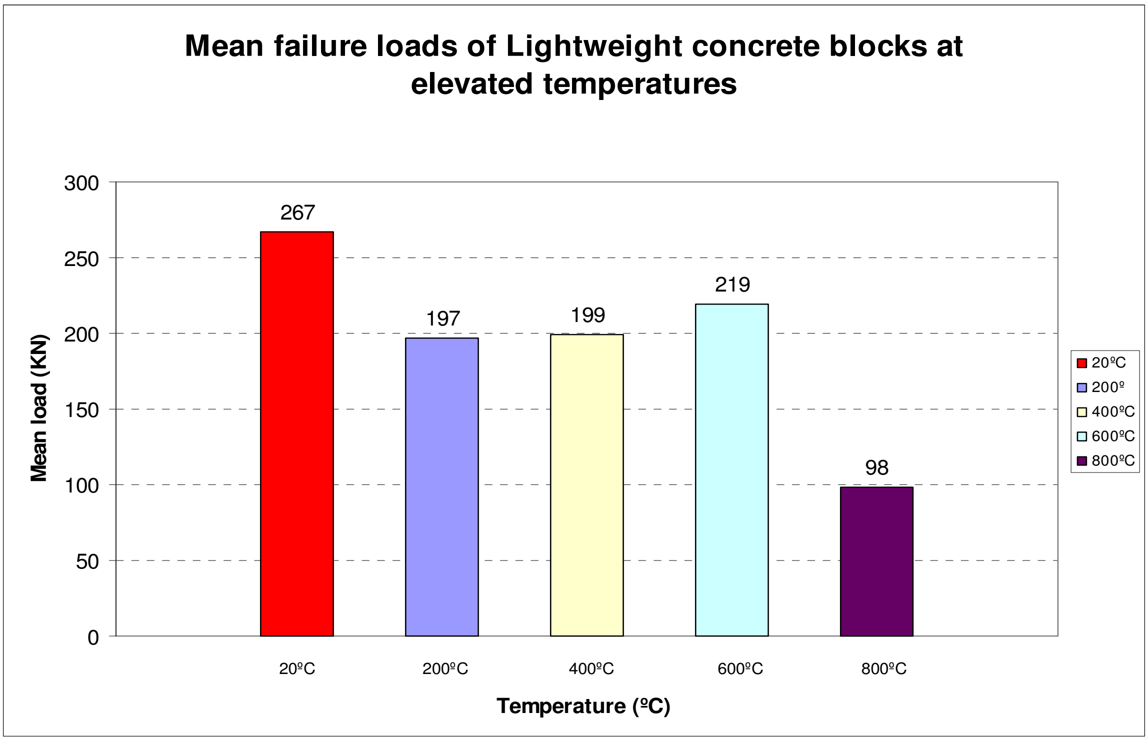


Figure 93: Average failure loads for blocks at high temperatures.

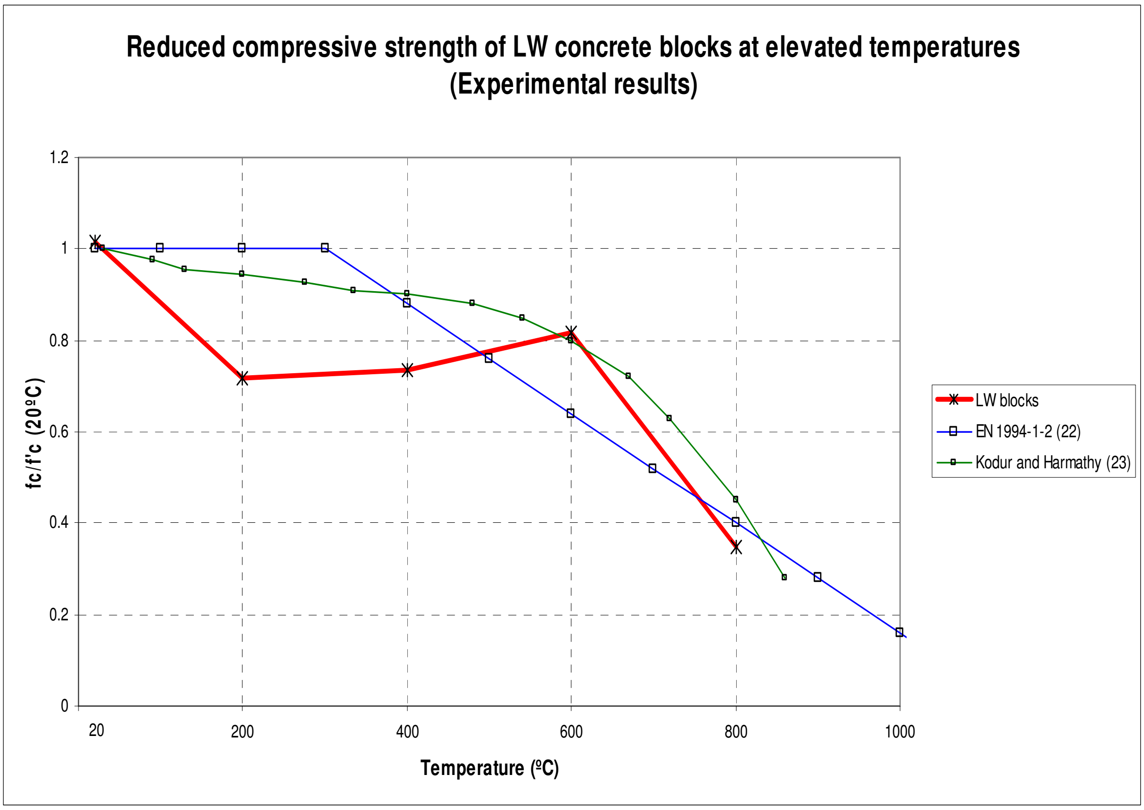


Figure 94: Reduced compressive strength of blocks at elevated temperatures.

The reduced compressive strength of the blocks is also compared against EN 1994-1-2 [22], which is one of the most immediate and available references and the comparison is not in a good match. It can be noted that with the second reference [23] the block results were in absolute disagreement from 20ºC to 600ºC. However, the reduced compressive heated block curve is in a good match after this temperature.

Table 4.5 presents the mean vertical deflections achieved during the block tests at high temperatures. Those values are from the corresponding failure loads. It can be seen that as the temperature increased, the deflections were larger.

Table 4.5 Average vertical deflections in the blocks at elevated temperatures.

Temperature (ºC)	Vertical deflections (mm)
20	1.802
200	2.179
400	2.659
600	3.505
800	7.206

4.2.2.4 Failure modes

The experimental investigations revealed that the majority of the blocks exposed to ambient and hot conditions predominantly failed by shear splitting. This type of failure was characterized by a diagonal rupture of the blocks in two parallel planes, forming two wedges. Figures 95 to 97 show the failure pattern in the blocks tested at ambient temperature, 200ºC and 400ºC respectively.

Figure 95: Failure modes of the blocks tested at ambient temperature.

Figure 96: Failure modes of the blocks tested at 200ºC

Figure 97: Failure modes of the blocks tested at 400ºC

The same type of failure that occurred in the blocks tested at lower temperatures was also exhibited in those tested at 600ºC and 800ºC. Although the blocks heated at 800ºC did not have a very visible shear failure as occurred in the other blocks, it can be observed that the tendency of the crack at one end of the blocks is to run diagonally. On the other hand, in addition to the shear failure, the same group of blocks suffered greater material expansion. The expansion of lightweight concrete has been mainly associated with the expansion of the cement paste and swelling, they are produced with the temperature achieved by the water contained in the pores [48].

Figure 98: Failure modes of the blocks tested at 600ºC

Figure 99: Failure modes of the blocks tested at 800ºC

It is also worth mentioning that in most of the blocks there were visible large cracks on the top face, which ran along the whole width. The presence of this type of failure in the blocks is correlated with tensile forces acting in a perpendicular direction to that at which the loads were applied [84].

4.2.2.5 Stiffness

Variation in the modulus of elasticity of the blocks at temperatures between ambient and 800ºC is shown in this section. The modulus was calculated from the stress-strain relationships of the average blocks at one third of the ultimate stress. The corresponding obtained values with temperature are presented in the Table 4.6.

Table 4.6 Modulus of elasticity values of blocks at high temperatures.

Temperature (ºC)	Modulus of elasticity (MPa)
20	937
200	504
400	423
600	357
800	79

From Figure 100, it can be appreciated that the Young's modulus was abruptly reduced at 200ºC in comparison with the modulus achieved at room temperature; this reduction was in the order of 46%. The variation, however, was more moderate in the range after 200ºC and up to 600ºC. The reduced values were 55% and 62% at 400ºC and 600ºC respectively.

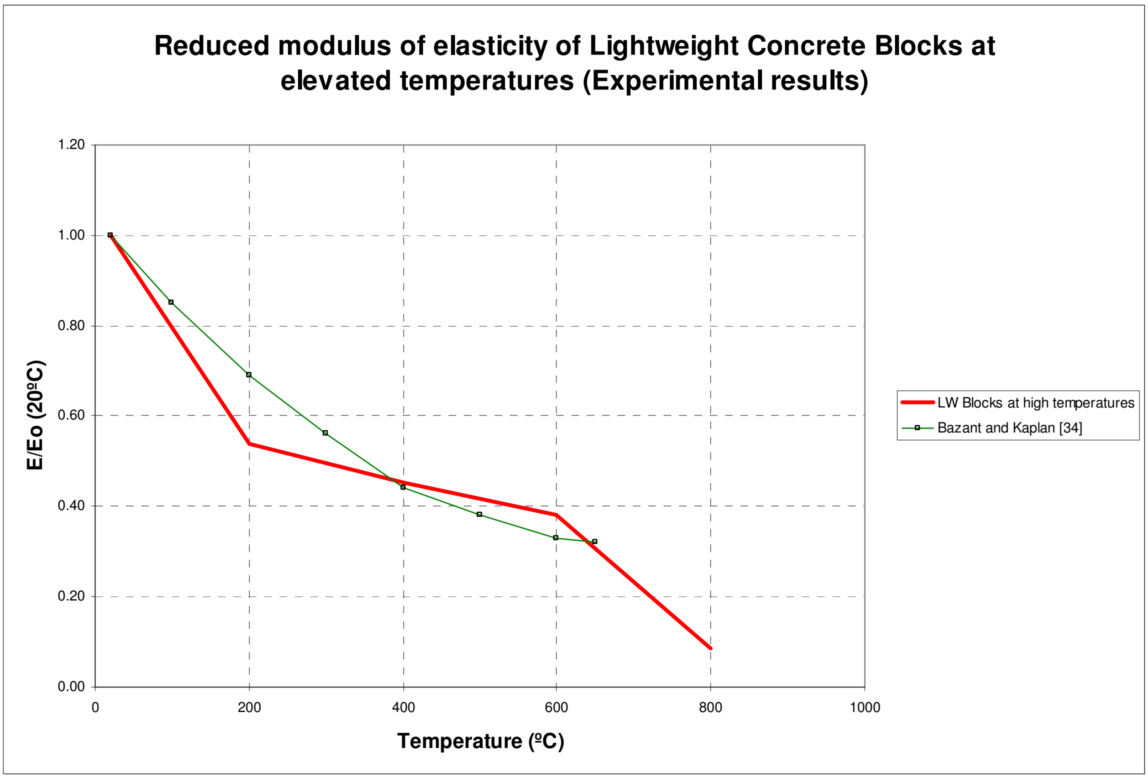


Figure 100: Reduced modulus of elasticity of LW concrete blocks at thermal conditions.

The modulus from the blocks heated and tested at 800ºC dropped to minimum values as shown in the same Figure. The reduction was in the order of 92% at this temperature. The modulus of elasticity is compared with results from Bazant and Kaplan [34], which have a general good agreement with those from the experimental lightweight concrete blocks.

4.2.2.6 Spalling

To complement the explanation in Section 4.2.1.6, a brief summary containing the main characteristics of the same type of spalling which occurred in the wallettes and in the blocks, is presented in the Table 4.7.

Table 4.7 Spalling features in the wallettes and blocks.

Temperature (ºC)	Level of spalling		Features
	Wallettes	Blocks	
200	Very low	Very low	No visual changes
400	Low	Low	Few spalled particles dropped in the furnace
600	Moderate	Medium	Few spalled particles were removed from blocks
700	High	-----	Spalled obsidian aggregates
800	Very high	Very High	Surfaces completely rough

One feature that was very distinctive from the wallettes tested at 700ºC and 800ºC and that was confirmed from the blocks tested at 800ºC is the spalling of expanded clay, which was one of the aggregate particles used for the block construction. As observed in Figure 101, the obsidian aggregate was completely spalled, leaving a hole in their original place at the surface of the blocks and wallettes. This can be appreciated by the black pigments in the same Figure.

Figure 101: Spalled wallette and block at 800ºC.

4.2.3 Mortar specimens

This information highlights the experimental results of mortar at elevated temperatures. The results enhance the reduction of the tensile capacity at ambient temperature, 200ºC and 400ºC; they are plotted as load-deflection relationships and expressed as N vs mm.

Generally, three specimens were cast to determine the tensile load-deflection relationship of mortar, but an inappropriate way of placing one of the specimen into the tensile machine, caused a premature failure of one of the specimens considered at this temperature. This meant that only two specimens were tested successfully at ambient temperature.

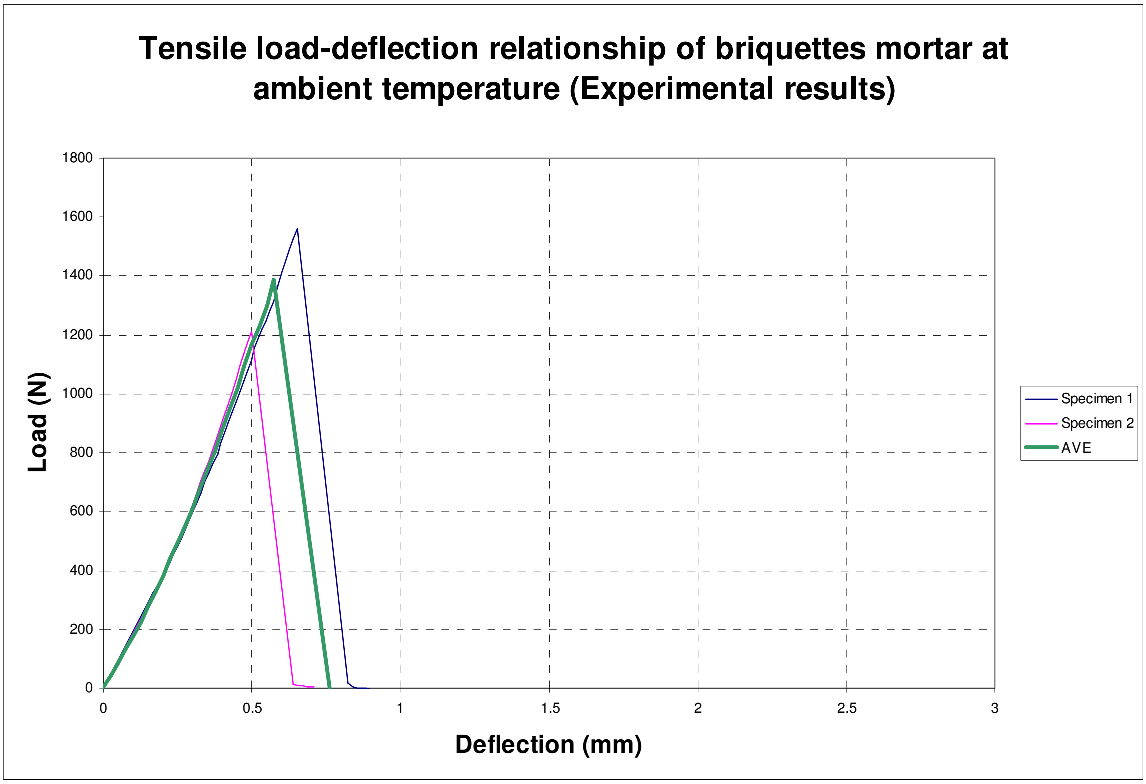


Figure 102: Tensile load-deflection relationship of mortar at ambient temperature.

Rather than knowing the fire-behaviour of mortar in tension, this information was required to input data into the Finite Element models to simulate masonry in fire.

4.2.3.1 Tensile load deflection relationship of mortar

Figure 102 shows the tensile load-deflection relationships of mortar briquettes or "dog-bone" shaped specimens tested at ambient temperature. These relationships are featured by a quasi linear shape up to the point in which the specimen achieved the maximum loads. After this, the load was very rapidly reduced to zero. The maximum load achieved in the specimen 1 was 1562.4N; the corresponding deflection was 0.65mm. The values for the second specimen were 1213.2N and 0.50mm respectively. The maximum average tensile load was 1390.0N and the average deflection was 0.58mm, which is represented by the thicker curve.

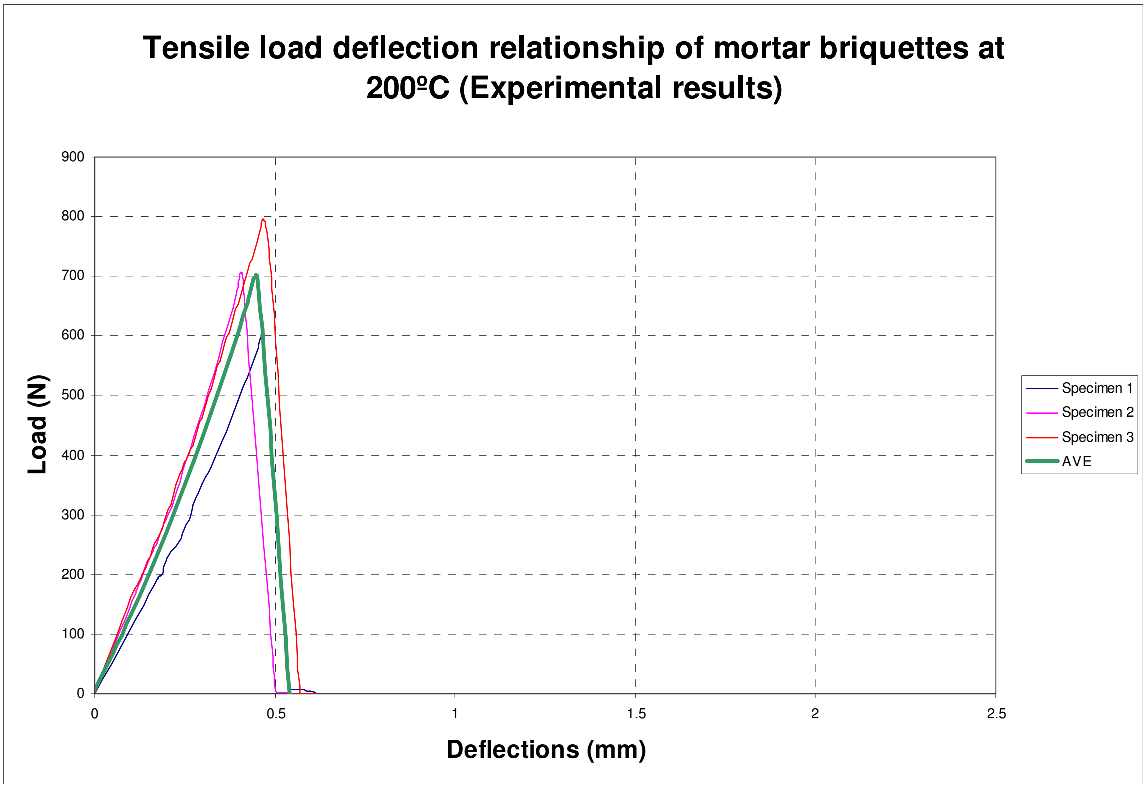


Figure 103: Tensile load-deflection relationship of mortar at 200ºC.

Additionally; the results obtained at 200ºC are shown in Figure 103. In this case, three specimens were tested successfully and they were plotted together alongside the average curve. In comparison with the previous results and despite of the linear behaviour, the results at 200ºC exhibited more variation in the curve shapes, but less variation in the maximum loads.

The maximum load for the average curve was 699N and the deflection was 0.45mm. The results from these specimens showed a more compacted range for the maximum loads, which was from 600N up to 795N, the corresponding deflections were 0.49mm and 0.47mm.

Finally, shown in Figure 104 are the details of the resulting load-deflection relationships of mortar specimens tested at 400ºC. The three curves followed the almost linear performance experienced in the previous test results. It can also be appreciated that these results kept a similar maximum load difference as occurred in tests at 200ºC.

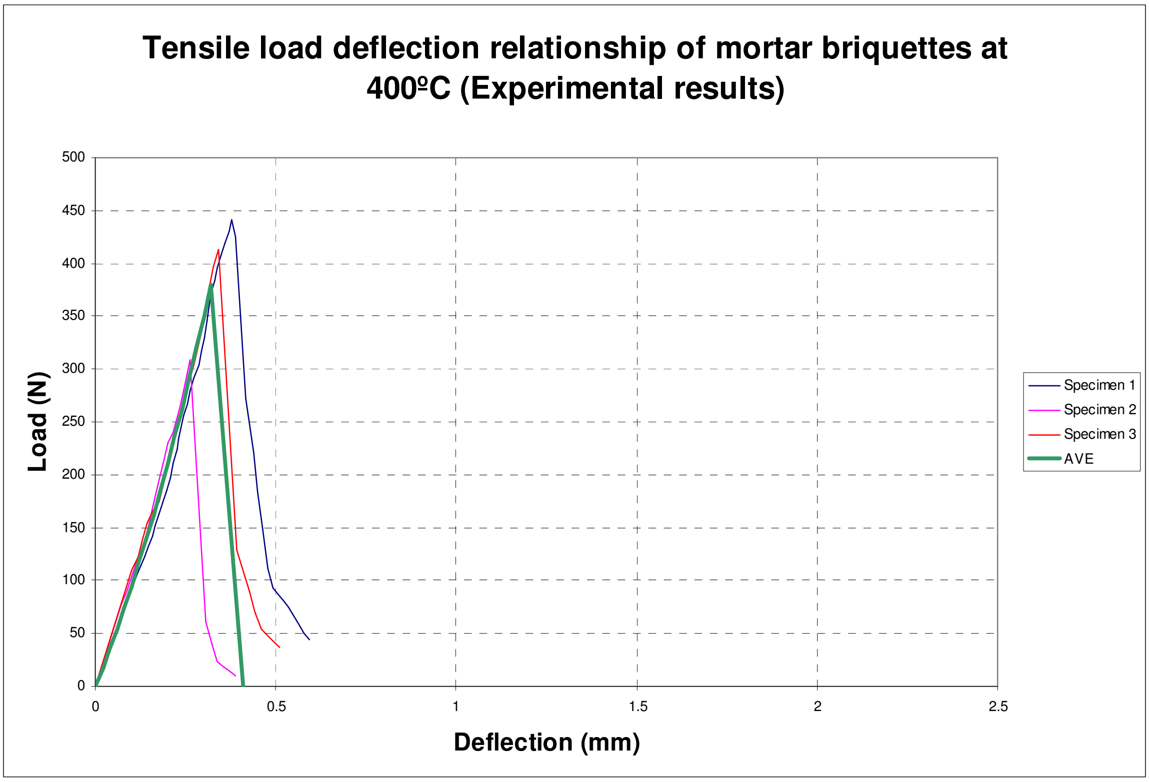


Figure 104: Tensile load-deflection relationship of mortar at 400ºC.

In these tests, the failure loads were ranged in the order of 309N and 441.5N; the deflections were 0.26mm and 0.38mm. The average tensile relationship had a maximum load of 380N and a corresponding deflection of 0.32mm.

4.2.3.2 Tensile strength of mortar at elevated temperatures

The reduction in the tensile strength of the mortar tested at ambient and elevated temperatures is discussed. Figure 105 shows the tensile strength of mortar. Each data point in this curve depicts the average tensile strength of the specimens from each temperature group. The tensile strength was obtained by a mathematical calculation, dividing the maximum load achieved between the cross sectional area of the specimen, and was normalized with the tensile strength obtained at ambient temperature.

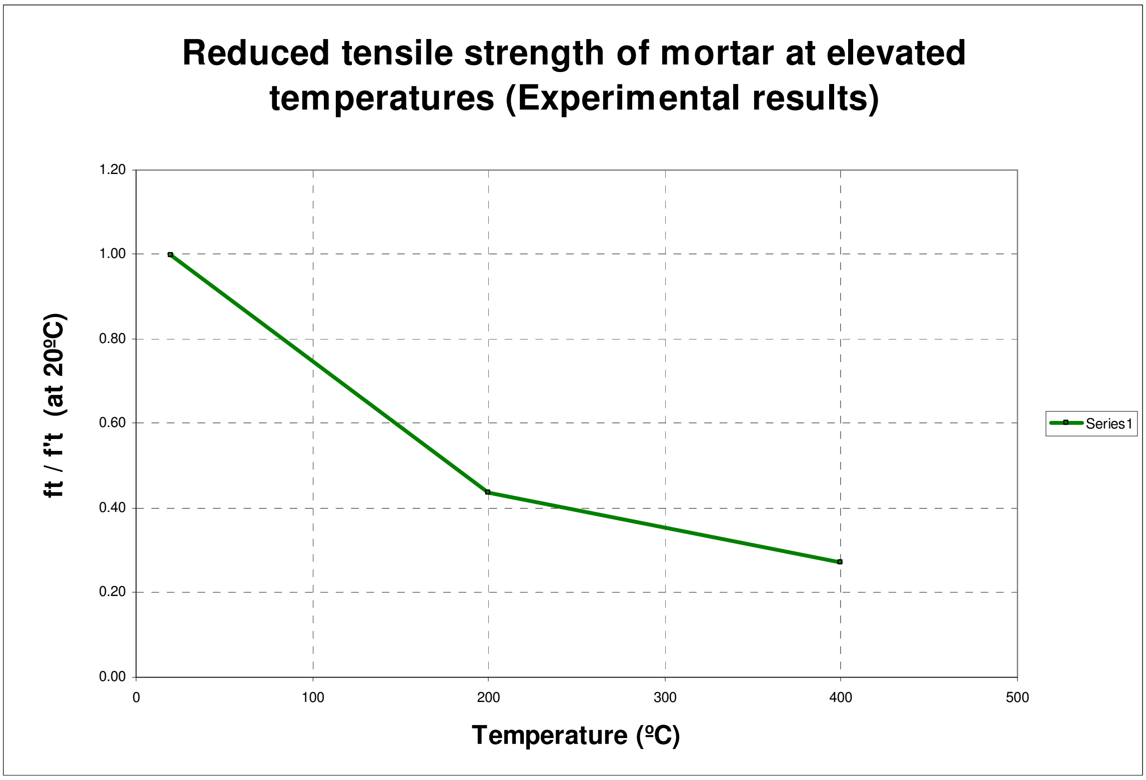


Figure 105: Reduced tensile strength of mortar with temperature.

It is interesting to observe that the tensile strength was rapidly reduced around 56% at 200ºC. Meanwhile, the reduction achieved in the specimens heated at 400ºC was in the order of 73%. Based on these results, the expected tendency is a greater decrease, than those obtained values, when higher temperatures are applied.

In conclusion, the performance of these tests to obtain the tensile strength at elevated temperature was characterized by an unexpected rapid decrease. This behaviour has been associated with an increment of the porosity level of the material when it is subjected to high temperatures [61].

4.2.3.3 Failure modes of the specimens subjected to tensile loads

This section enhances the failure modes achieved in the specimens used to determine the mortar tensile capacity at elevated temperatures. Figure 106 shows the final failure stages of all the specimens tested at ambient temperature (at left side), 200ºC (at right bottom side) and 400ºC (at right upper side).

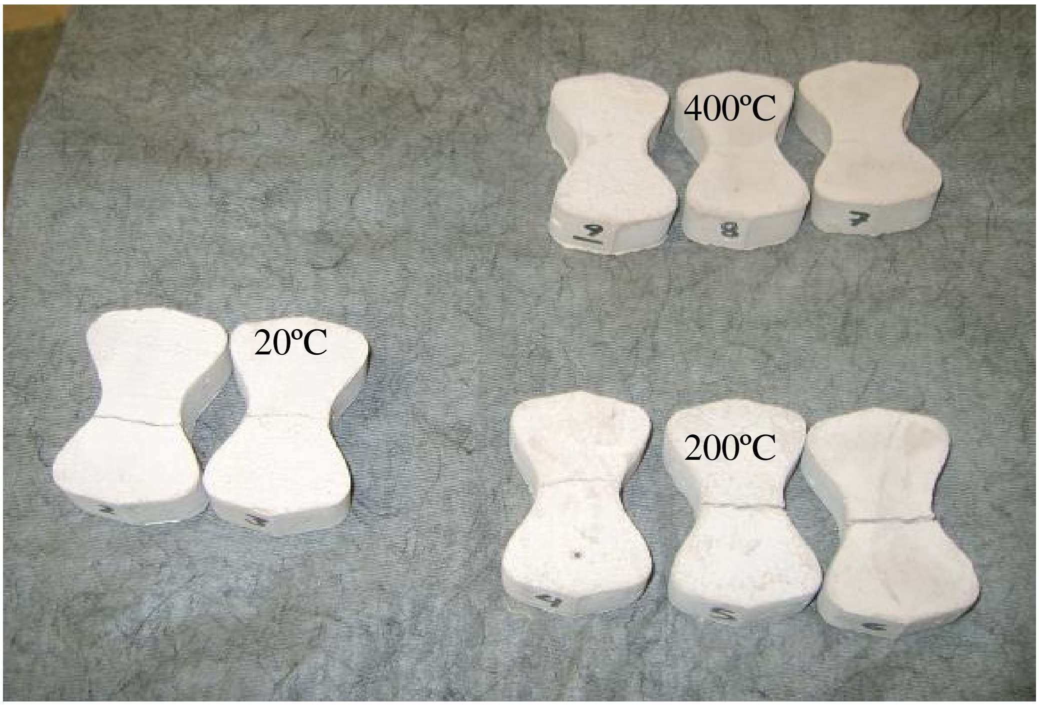


Figure 106: Failure modes of mortar at elevated temperatures.

As appreciated in the photograph, all the specimens achieved the same failure pattern. During testing, it was observed that initial visible cracking appeared along the thinner part of the specimen, which was propagated faster or slower as the temperature of the material increased. This initial cracking appeared in the area, in which the greater tensile forces were expected to occur.

4.3 Comparison of the experimental wallette and LW block results

This section compares some results obtained from the masonry wallettes and the individual tests on lightweight concrete blocks at elevated temperatures. The comparison is about the reduced compressive strength and the modulus of elasticity from the experiments in the laboratory.

4.3.1 *Reduced compressive strength at elevated temperatures*

Figure 107 shows a comparison of the experimental results obtained from the masonry wallettes at elevated temperatures and similar results from individual lightweight concrete blocks tested at identical conditions than the wallettes.

This study is based on the reduction in the compressive strength of the wallettes and the lightweight concrete blocks. Evidently the results show a general poor match until 500ºC in which the compressive strength of the lightweight blocks is assumed to be more affected by the very longer heating periods discussed in Section 4.2.2.1. Due to this, the comparison at this temperature is unexpectedly lower for the curve of the blocks.

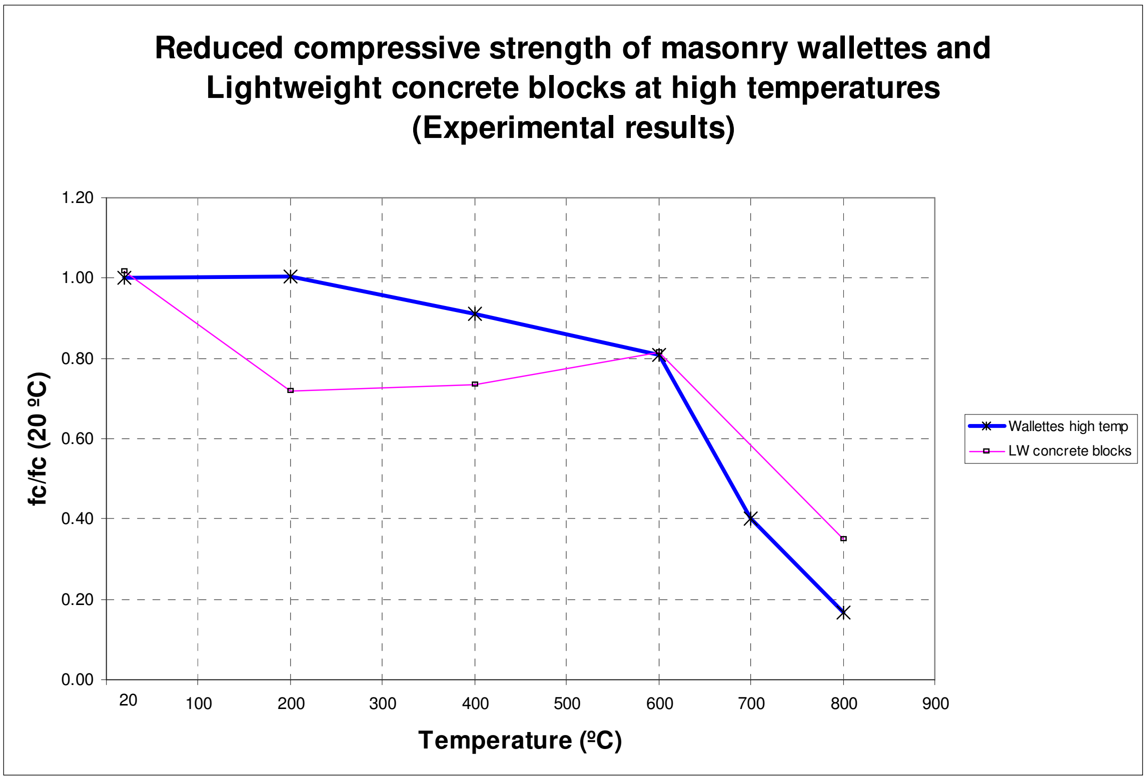


Figure 107: Reduced compressive strength of wallettes vs LW blocks with temperature.

This assumption is based on the theory that the compressive strength of the wallettes depends on their two components (from which the unit is one of them) and that it should be lower than the compressive strength of the units [29]. This comparison shows an evident greater compressive strength of the blocks from 600ºC to 800ºC. At 200ºC the difference is about 28% greater for the compressive strength of the wallettes.

At 400ºC the compressive strength of the wallettes is approximately 18% greater than that for the blocks. A difference at 600ºC was not achieved, and finally, the compressive strength of the blocks is 18% greater than that in the wallettes at 800ºC.

4.3.2 Reduced modulus of elasticity at elevated temperatures

The reduced modulus of elasticity from the masonry wallettes and the lightweight concrete blocks is compared in Figure 108. The curve of the wallettes is higher along all the temperatures up to 580ºC at which the modulus of the blocks is slightly greater than that in the wallettes up to 800ºC.

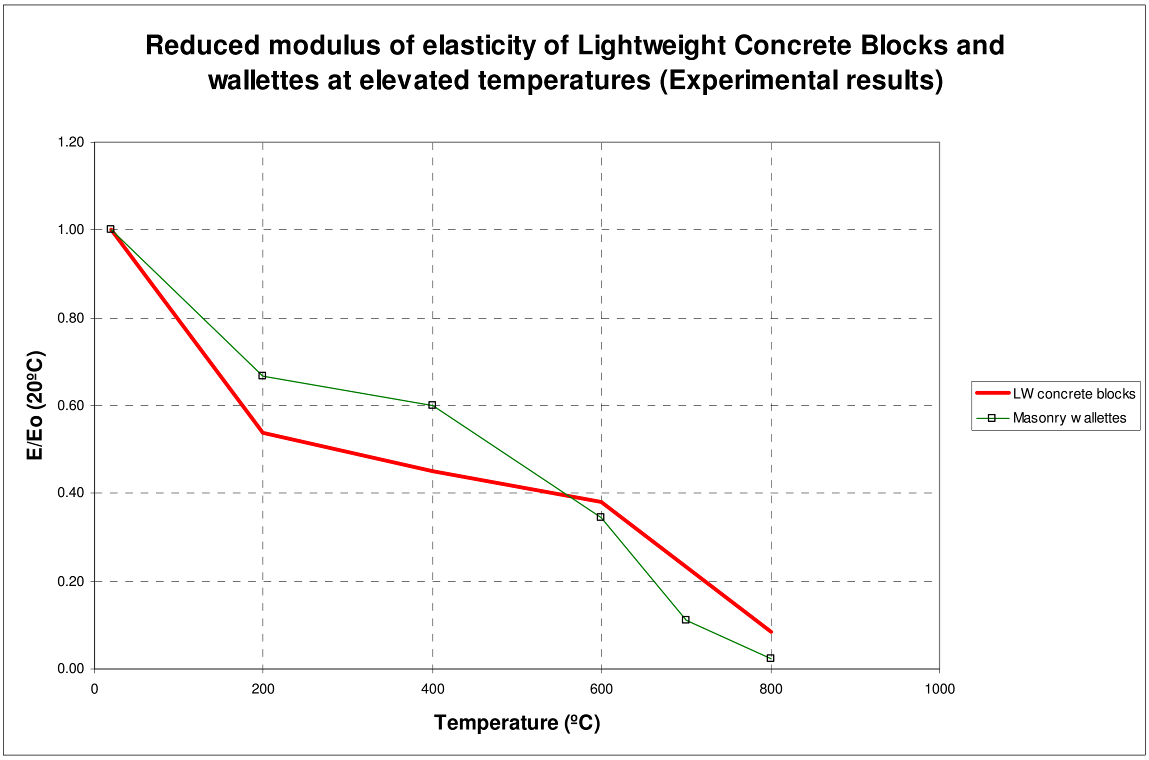


Figure 108: Reduce modulus of elasticity of wallettes vs LW blocks with temperature.

The modulus from the wallettes was 13% greater than that in the blocks at 200ºC. At 400ºC the reduced modulus of the wallettes was 15% greater than the modulus of the Lightweight concrete blocks. At 600ºC the difference was changed to 3% greater for the curve of the blocks; finally, at 800ºC the modulus of the blocks had a greater percentage, which was in the order of 6%.

Chapter 5

Finite Element Model

5.1 Introduction

The scope of this Chapter is to describe the Finite Element Method to simulate the fire behaviour of the masonry wallettes. The F.E. analyses were divided into structural and thermal behaviour to model the mechanical and thermal properties of the masonry specimens respectively. The results from this numerical technique are presented and validated with the experimental results obtained from the wallette tests.

The results obtained from these experimental and numerical investigations were taken to predict the fire behaviour of 3m height masonry walls, whose response is focused on the same variables obtained from the wallettes and compared with existing similar results.

The damage plasticity concrete concept was used to model the lightweight concrete blocks in the wallettes; meanwhile, elastic spring elements were considered to reproduce the nonlinear mortar behaviour. They were taken into account to develop the F.E.M. structural analyses to obtain stress-strain responses. For the thermal behaviour, a different concept based on the thermal material properties and the heat transfer modes was considered.

5.2 Finite Element Model

The Finite Element Method (F.E.M.) is a numerical technique that has been successfully adopted to study special cases where, for instance, stress-strain distribution is required. In the past, due to the complexity of the problems, it was difficult to discretize them in the same manner, taken much time and effort; however, the development and use of sophisticated software has now improved this situation [119].

The F.E.M. concept was then applied to simulate the performance of the experimental wallettes tested at elevated temperatures. The numerical evaluations were developed with the use of the commercial software package ABAQUS [120], which can effectively analyse the non-linear behaviour of concrete and the heat transfer modes.

As stated in previous chapters, the performance based method was adopted to study the fire behaviour of the wallettes; this methodology requires the evaluation of three components: fire modelling, thermal and structural analyses [16], which are described as follows:

5.2.1 Structural Modelling

The structural response is required to evaluate the reduction in stiffness and material strength in a member based on static load. For the structural analysis, both lightweight concrete blocks and mortar were modelled using different concepts. Thus, the following parts were necessitated:

5.2.1.1 Lightweight concrete blocks

Solid bricks elements were chosen to model lightweight concrete blocks, the following sub-parts were also required.

5.2.1.1.1 Element type and finite element mesh

The C3D8 solid element was used to model lightweight concrete blocks; this is a three dimensional continuum brick element with eight nodes (see Figure 109).

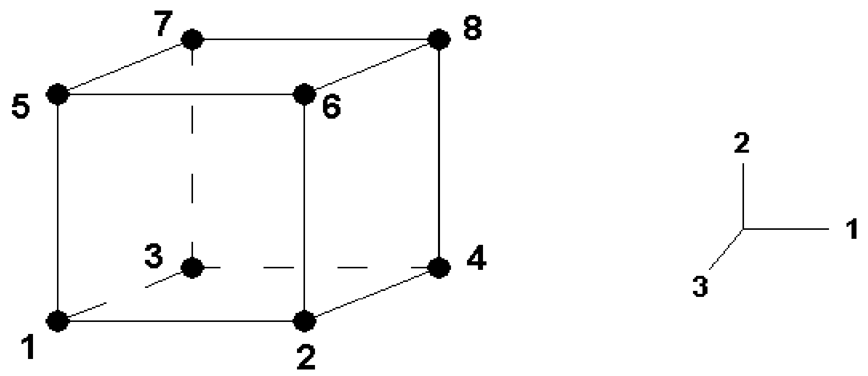


Figure 109: C3D8 solid element used for modelling LW blocks.

A mesh size of 10x10x20mm (l x h x t) was used to provide accurate results from the F.E. analysis. This mesh type has six degrees of freedom at each node, which are three displacements and three rotations. Based on the mortar thickness, the size of the mesh was determined. Figure 110 shows the finite element mesh used in a whole block.

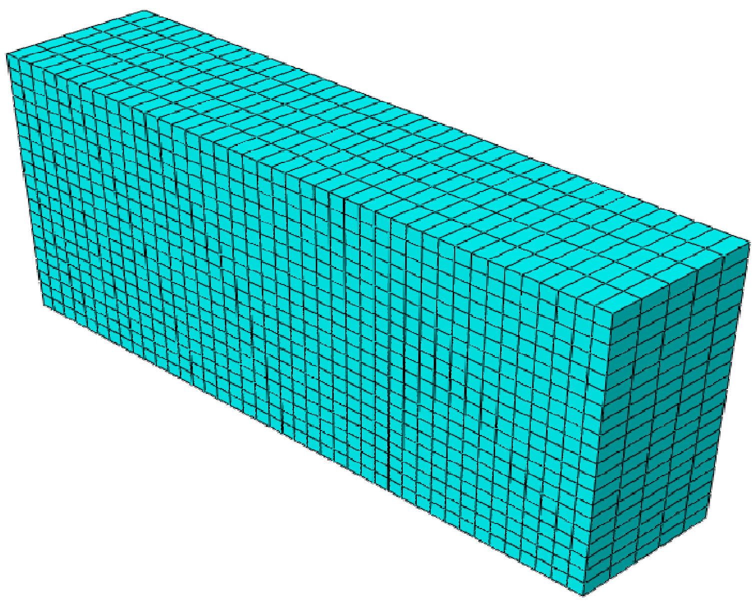


Figure 110: Mesh element used for FE analysis.

5.2.1.1.2 Material model

Concrete damaged plasticity was selected as the material model to simulate the behaviour of the lightweight concrete blocks in the wallettes at different temperatures. The model, Figure 111, assumes that the concrete material fails due to tensile cracking and compressive crushing; the tensile and compressive responses are featured by damaged plasticity [120].

The damaged plasticity model uses a combination of concepts such as isotropic damaged elasticity and isotropic compressive and tensile plasticity to simulate the inelastic concrete behaviour. This model also considers that the damage that occurs in the concrete is irreversible.

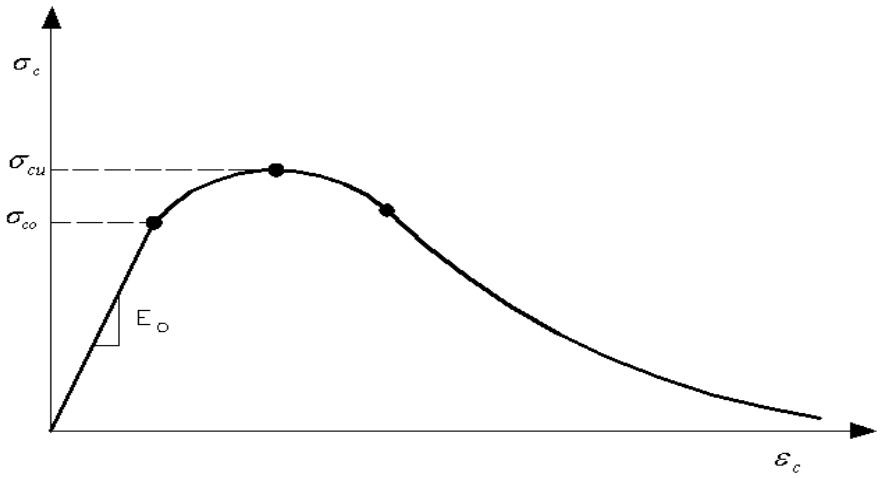


Figure 111: Material model in compression [120].

It is supposed that the compressive behaviour is linear up to the yield point, denoted by σ_{co} . The plastic region, located between the yield point and the ultimate stress (σ_{cu}), depicts stress hardening followed by strain softening.

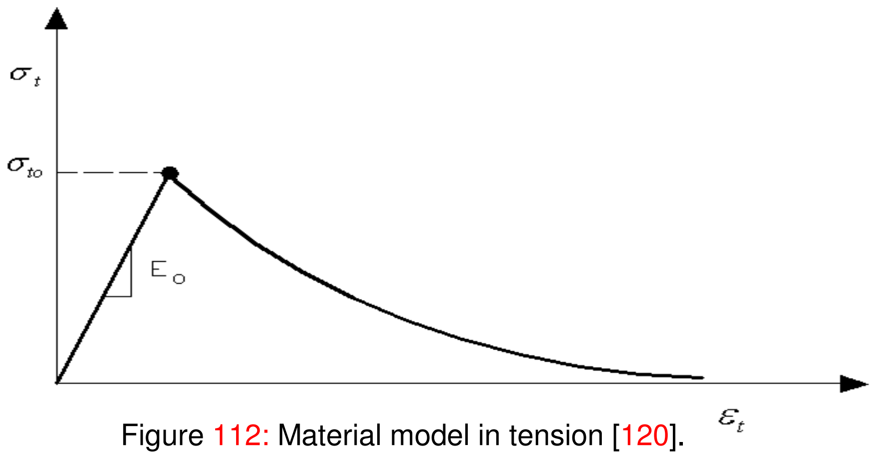


Figure 112: Material model in tension [120].

As shown in Figure 112, the stress-strain relationship in tension is assumed to be linear up to the ultimate stress, denoted by σ_{to} . After the tensile failure is achieved, the model considers that micro-cracks are formed in the concrete and the strength decreases up to failure. This behaviour is represented by a softening descending stress-strain response [120].

The compressive stress-strain relationships of the lightweight concrete blocks at elevated temperatures used for the analyses were taken as average values from the experimental results previously discussed in Chapter 4.

As block tensile tests with temperature were not carried out experimentally, parametric studies were conducted to determine data for the tensile strength for the masonry analysis. Additionally, reported values from standard tests were taken, such as 10N m/mm^2, which is a typical fracture energy value of lightweight concrete [121].

5.2.1.2 Mortar

To model the mortar used in the wallettes, springs elements were employed. Recently, the use of the springs has been applied successfully to simulate the behaviour of masonry [122,124,125].

For the numerical analysis, the springs were used not only to model the mortar material behaviour, but also to prevent induction of any interaction problem between the mortar and the lightweight blocks. These elastic elements are available at the ABAQUS element library, whose most important features are to couple loads with displacements and to be treated as linear or nonlinear; the spring used acts between two nodes and performs along its line of action as observed in Figure 113.

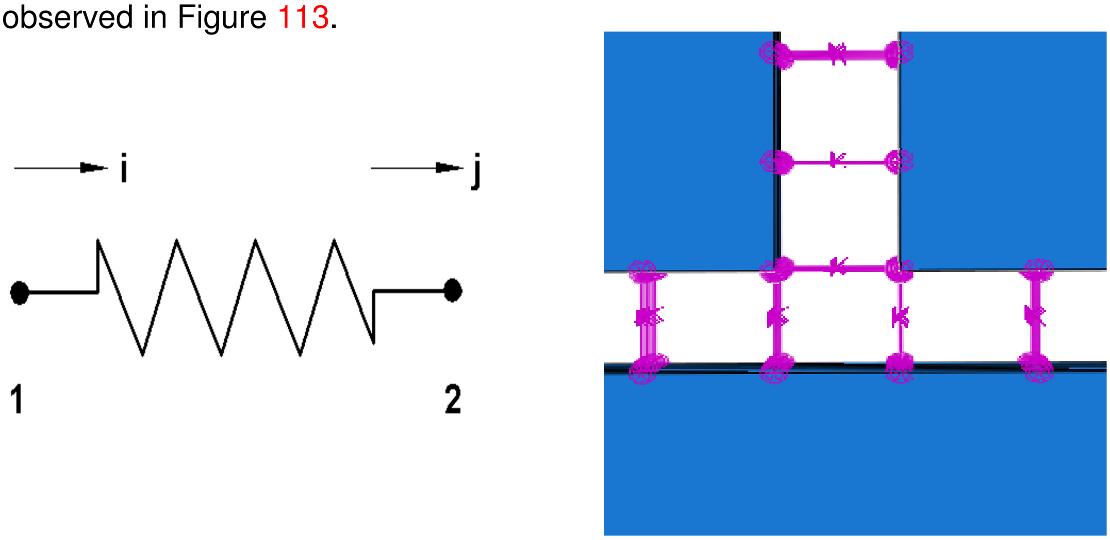


Figure 113: Spring elements used to simulate mortar material [120].

Due to the nonlinearity exhibited by mortar during fire, nonlinear spring elements were therefore required to simulate its behaviour. To define the nonlinear performance, pairs of force relative-displacement were necessitated. Figure 114 shows typical nonlinear spring behaviour; ABAQUS does not require values outside the range shown in the same Figure, because it is assumed that the maximum forces (in compression and in tension) remain constant inducing zero stiffness [120].

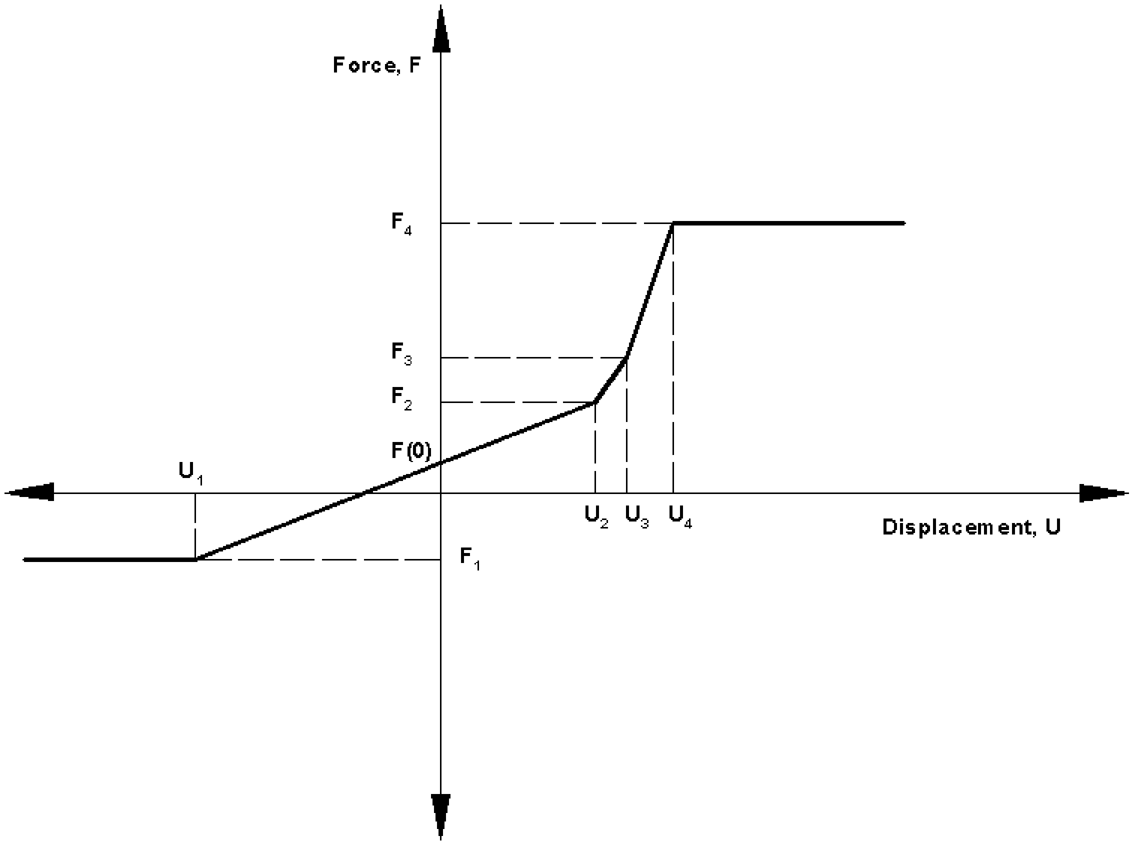


Figure 114: Nonlinear spring force-relative displacement relationship [120].

Figure 115 shows the mechanical properties of the mortar used to simulate its behaviour at elevated temperatures, the stress-strain relationships are expressed in compression and in tension. These properties are plotted for 20ºC, 400ºC, 600ºC and 800ºC as the temperatures used to determine the wallette responses by ABAQUS. The stress-strain mortar relationships were determined from parametric studies.

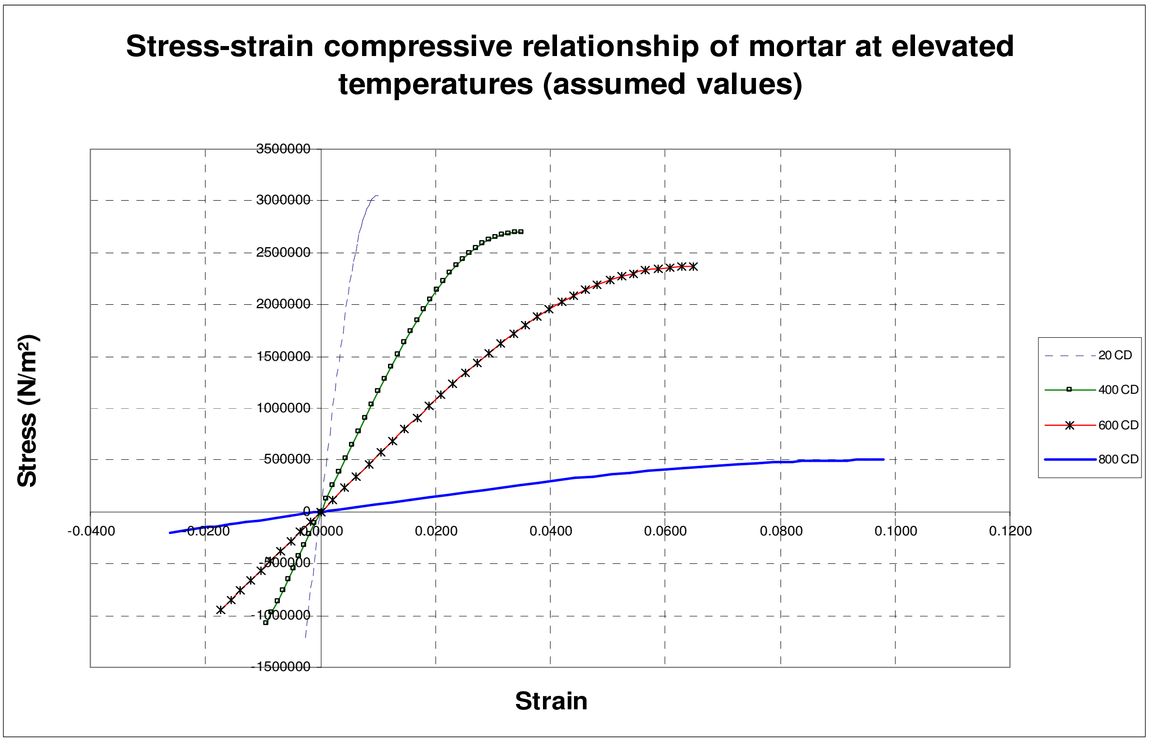


Figure 115: Stress-strain compressive and tensile relationships used to model mortar behaviour at elevated temperatures [56].

5.2.1.3 Boundary conditions

Identical conditions, at which the experimental wallettes were restrained, were also applied in the finite element model. All the nodes at the bottom of the model were only restrained in the Y direction. Details of boundary conditions applied in the model can be observed in Figure 116.

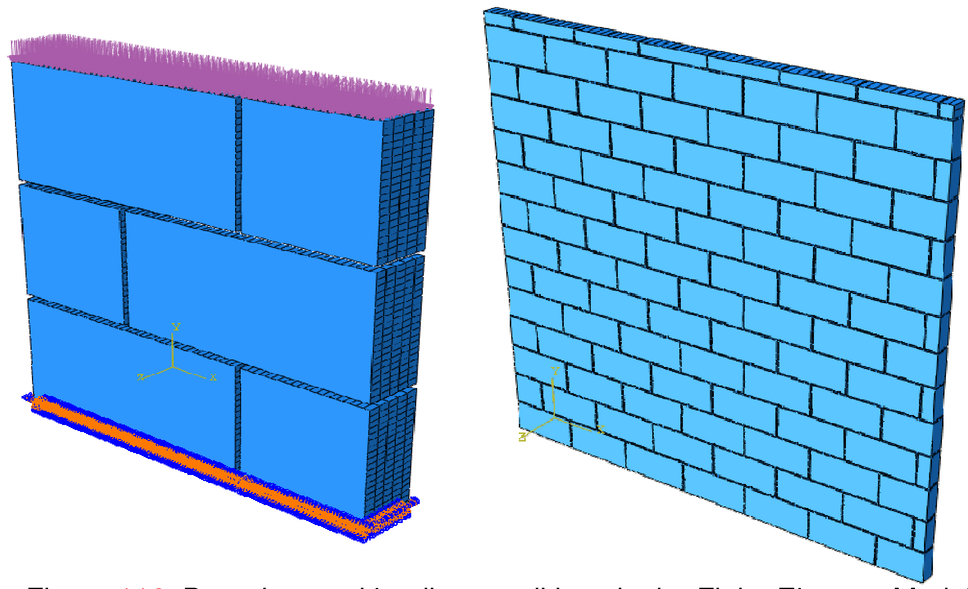


Figure 116: Boundary and loading conditions in the Finite Element Models.

5.2.1.4 Load application

The compressive loads were applied at the top of the model, as shown in Figure 116; the option "pressure" available in ABAQUS was chosen to simulate the crushing loads in all the top nodes. The value of the load used in the model was the average of the failure loads obtained in the three wallettes tested at the same temperature.

5.2.2 Thermal Modelling

Thermal analyses were required to simulate the heat transfer modes in the wallette models based on the thermal experimental results. According to EN 1991-1-2 [126], the net flux has to be determined for the convection and radiation modes as follows:

$$\dot{h}_{net} = \dot{h}_{net,c} + \dot{h}_{net,r} \tag{8}$$

Where, the net convective heat flux ($\dot{h}_{net,c}$) is determined by:

$$\dot{h}_{net,c} = \alpha_c \cdot (\Theta_g - \Theta_m) \tag{9}$$

Where:

α_c is the coefficient of the heat transfer by convection [W/m²K]

Θ_g is the temperature exposed in the member [ºC]

Θ_m is the temperature in the surface of the member [ºC]

In addition, the net heat flux for radiation ($\dot{h}_{net,r}$) is calculated by:

$$\dot{h}_{net,r} = \phi \cdot \varepsilon_m \cdot \varepsilon_f \cdot \sigma \cdot \left[(\Theta_r + 273)^4 - (\Theta_m + 273)^4 \right] \tag{10}$$

Where:

ϕ is the configuration factor (≤ 1.0)

ε_m is the surface emissivity of the member

ε_f is the emissivity of the fire (=1.0)

σ is the Stephan Boltzmann constant (5.67 x 10^{-8} W/m²K^4)

Θ_r is the effective radiation temperature of the fire environment (ºC)

Θ_m is the surface temperature of the member (ºC)

The emissivity term in the radiation formula was taken as 0.7. Table 5.1 shows the convective coefficients used for the thermal analyses at different temperatures.

Table 5.1 Convective coefficients used for thermal analysis of the masonry wallettes.

Temperature (ºC)	Convective coefficients (W/m²K)	
	Hot surfaces	Cold surfaces
200	25	4
400	25	4
600	25	4
700	25	4
800	25	4

To solve the convective formula (9), ABAQUS requires a surface film condition interaction. For this type of interaction the surface (the film load type), a sink temperature and a film coefficient need to be defined; the film coefficient refers to the term α_c expressed in the same formula previously.

Additionally, in ABAQUS the formula of radiation has to be evaluated by the use of a radiation surface interaction; for which, the affected surface by radiation, type of radiation, emissivity, the temperature at the surface of the member and the ambient temperature are required. This option is available in the ABAQUS library. On the other hand, conduction occurs across a medium [57]; thus, some properties of the wallette materials were required to simulate this mode.

5.2.2.1 Element type

For the thermal analyses, lightweight concrete blocks and mortar were modelled using the element DC3D8; this element is an eight-node linear heat transfer brick.

5.2.2.2 Materials

At this section the most important properties used for the thermal analyses of the wallettes are presented. Table 5.2 presents the thermal conductivity values, which where obtained from parametric studies, used for modelling lightweight concrete blocks and the mortar at different temperatures.

Table 5.2 Thermal conductivity values for thermal analysis

Temperature (ºC)	Thermal conductivity (W/m²K)	
	Lightweight concrete blocks	Mortar
200	0.33	2.9
400	0.33	1.4
600	0.33	1.4
700	0.32	1.4
800	0.32	1.4

Moreover, the density values applied in the analyses were 1400Kg/m³ for lightweight concrete blocks and 1900Kg/m³ for mortar at all the temperature targets; these values were obtained from the experimental results under dry conditions.

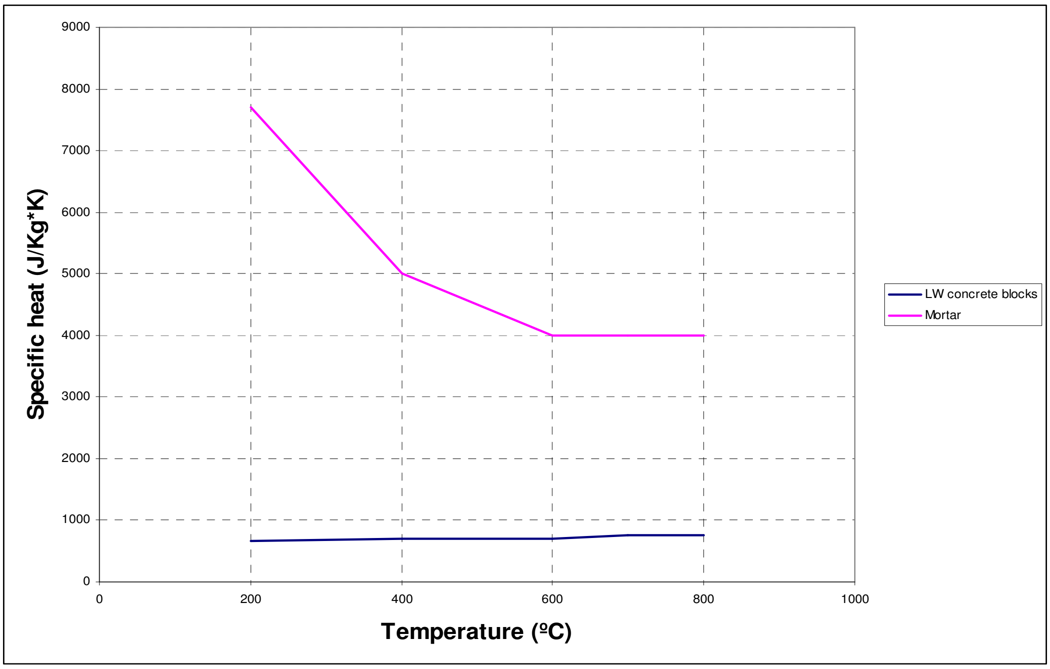


Figure 117: LW concrete and mortar specific heat values used for the thermal analyses of the wallettes and walls.

Figure 117 presents the specific heat values inputted into the thermal numerical evaluations. Lightweight concrete blocks and mortar specific heat curves are presented together. It should be noted that both values were obtained from parametric studies. Another thermal property was obtained from parametric studies to be incorporated in the thermal analyses; latent heat was required to simulate the plateau phenomenon that appeared at approximately 100ºC in the wallettes during the heating phases. In the case of lightweight concrete blocks a constant value of 48000j/Kg·K was applied, meanwhile, for mortar 89000j/Kg·K was used for the same temperature targets.

5.2.3 Fire modelling

For this phase, the severity of the fire in structural members has to be calculated; nominal or standard temperature-time relationships are usually adopted to represent a fire; which for the case of the wallette analyses, the furnace temperature measured from the experimental investigations was used.

5.3 Finite Element results

This section is divided into thermal and structural parts. The F.E. results are mainly shown in graphics; they are also compared with the experimental results obtained in the fire laboratory.

5.3.1 Results from thermal analyses of the masonry wallettes with temperature

In this section, the results from the thermal analyses of the wallette models are presented. They are expressed as temperature-time responses. Each graph contains the same thermal curves obtained from the experimental wallettes at different temperatures and discussed in the previous chapter. Eventually, a comparison between the thermal experimental responses and the results obtained from F.E. analyses is made.

The maximum temperatures achieved in both experimental and numerical evaluations are presented and compared in Table 5.3. A high degree of similarity can be seen between the values of both responses.

Table 5.3 Comparison of experimental and F.E.M. results

Temperature (ºC)	Maximum temperatures (ºC)				Ratio (Num / Exp)	
	Experiments		F.E. analyses			
	LW blocks	Mortar	LW blocks	Mortar	LW blocks	Mortar
200	200	200	199	198	0.99	0.99
400	401	403	388	388	0.97	0.96
600	600	602	588	591	0.98	0.98
700	699	704	696	697	0.99	0.99
800	800	802	793	794	0.99	0.99

A good general agreement between the curves from the experimental wallettes and those from F.E. analyses is shown in Figure 118. It can be observed that the curve representing measured mortar temperature follows that from the FE analysis well. Due to a quasi-similar behaviour, only one curve from the numerical analyses that depicts the mortar was plotted.

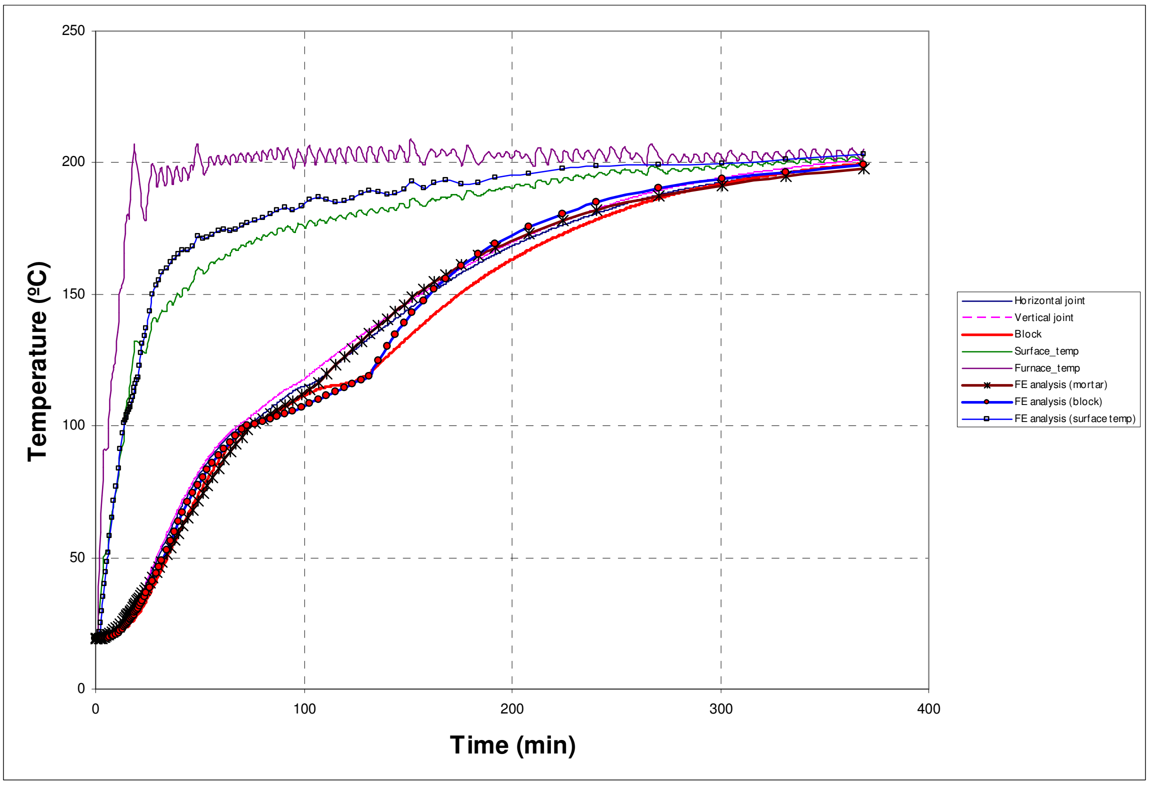


Figure 118: Comparison of experimental and numerical results of wallettes at 200ºC.

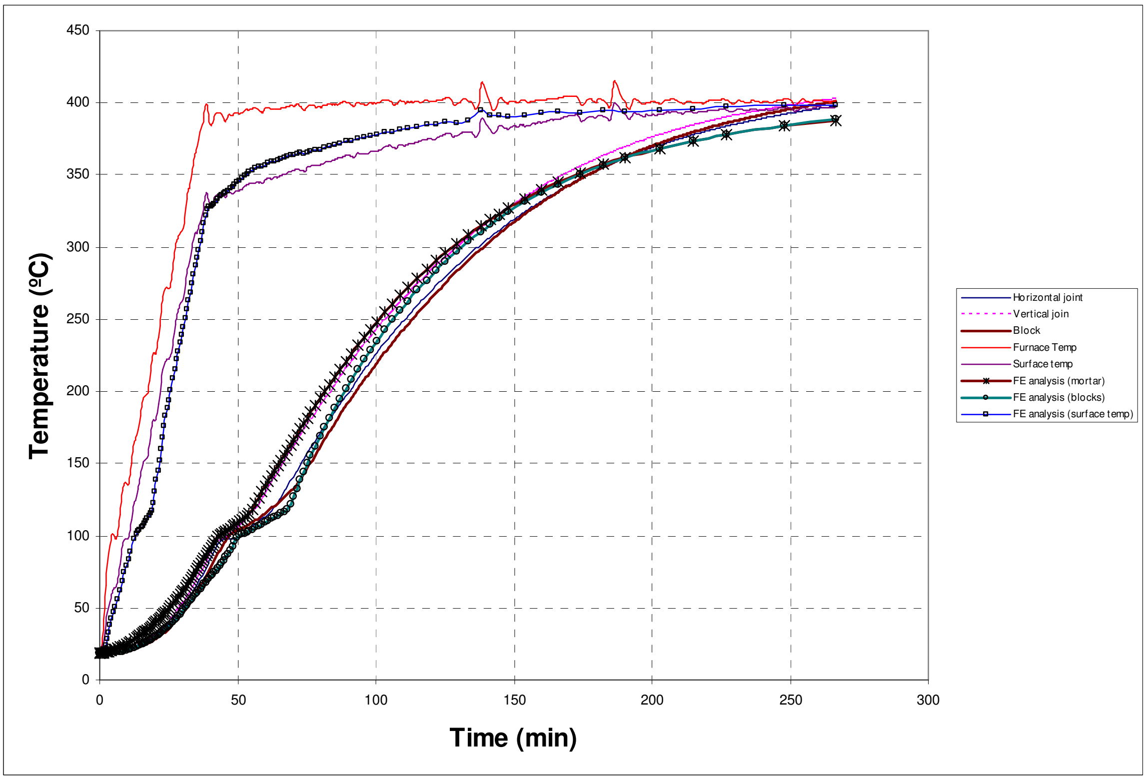


Figure 119: Comparison of experimental and numerical results of wallettes at 400ºC.

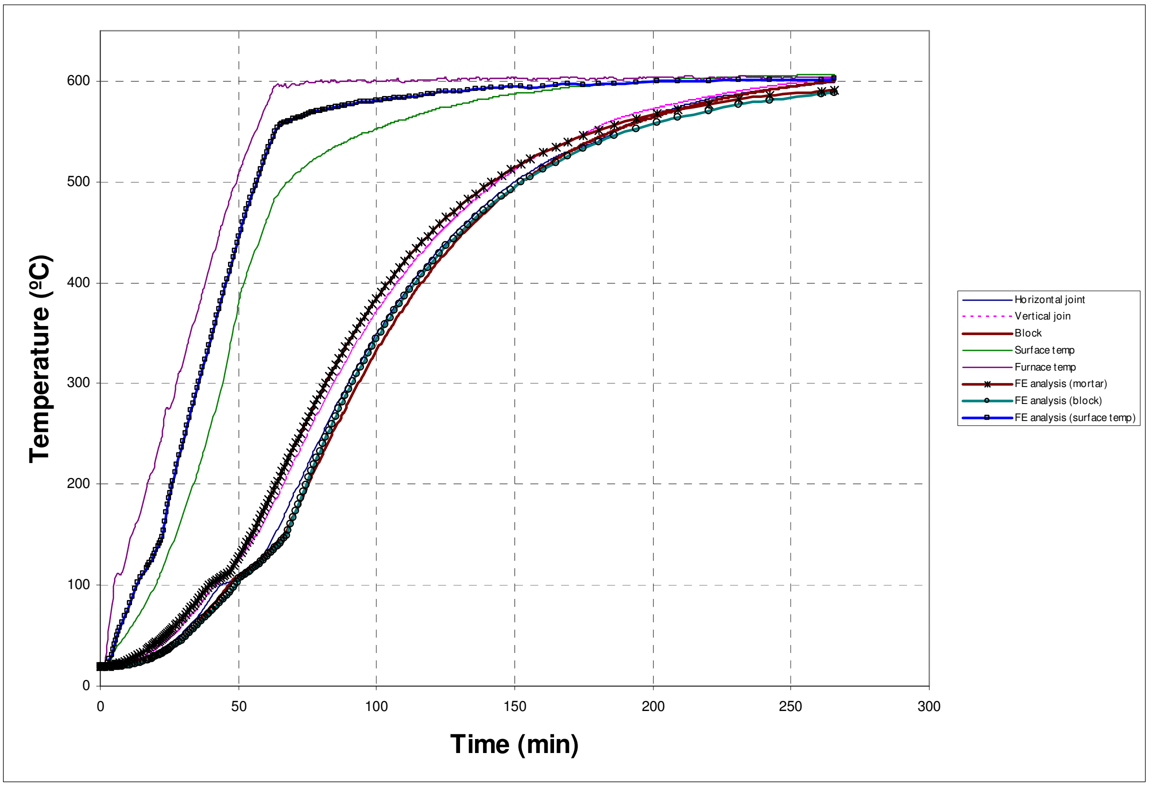


Figure 120: Comparison of experimental and numerical results of wallettes at 600ºC.

The curve, that shows the lightweight block temperature at 200ºC from F.E. evaluations, was a good match to the curve obtained from the experimental wallettes until the plateau phase finished. However, although the same curve did not match the experimental block curve, after the plateau period, the difference was not significant.

Similar approximations were experimented with the results of the wallettes exposed to higher temperatures. Figures 119 to 122 show the temperature-time responses of the wallettes at 400ºC, 600ºC, 700ºC and 800ºC. It is interesting to note that as the temperature rose (especially at 700ºC and 800ºC), the final results improved slightly.

The numerical and experimental temperature –time responses from the surface in the wallettes did not match to the same level as with the other comparisons. The numerical results did not consider that the surface temperature obtained in the experimental tests was affected by the inconstant position of the wallette attached in the surface due to the lower fire resistance of the adhesive used.

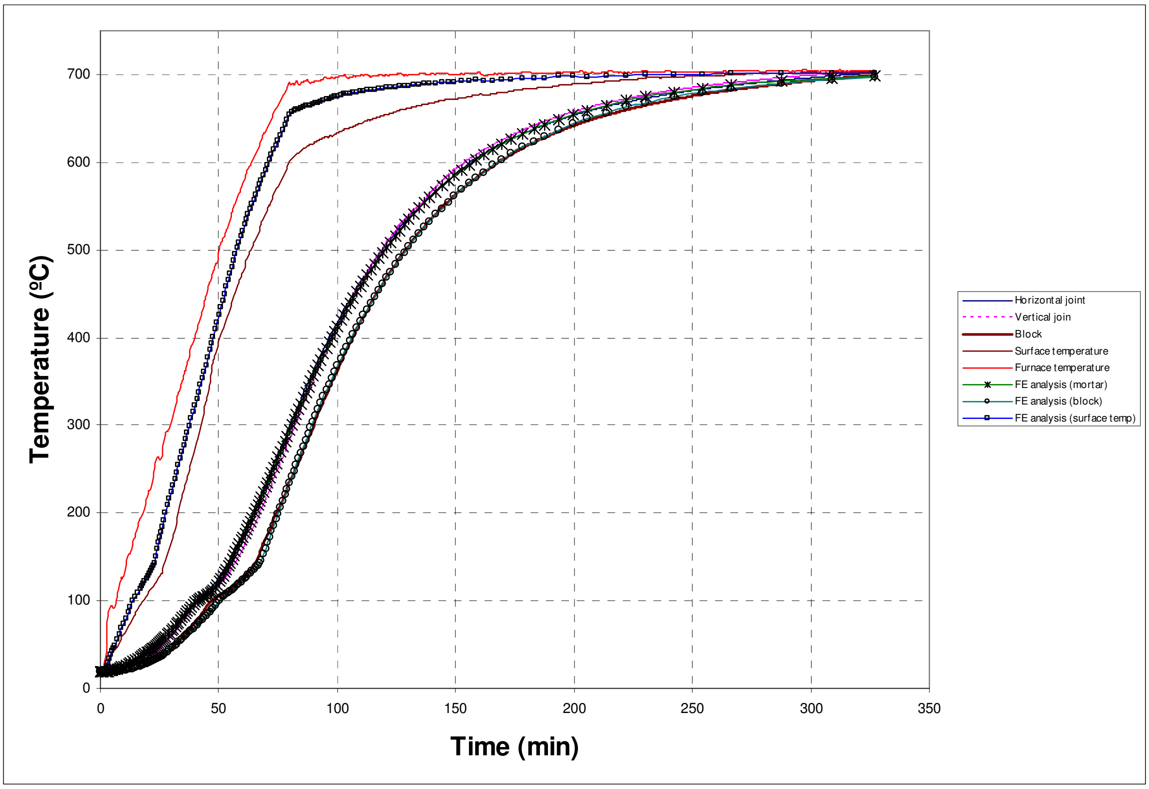


Figure 121: Comparison of experimental and numerical results of wallettes at 700ºC.

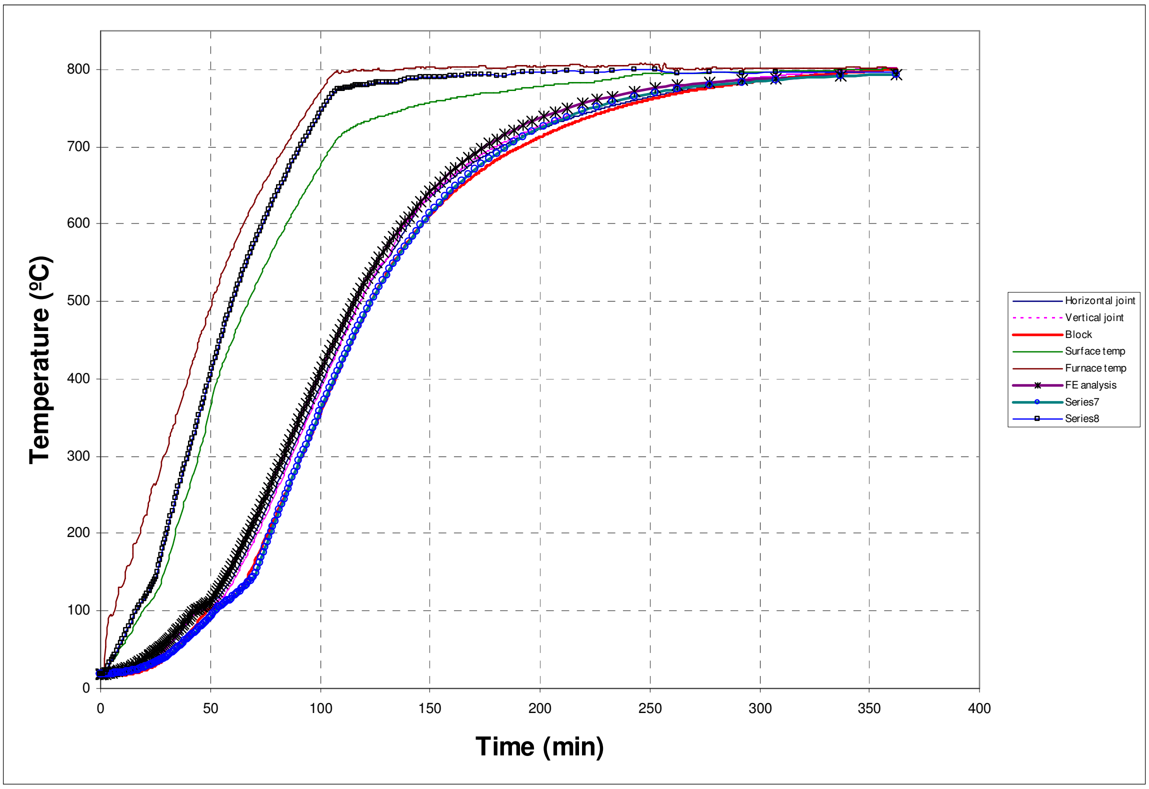


Figure 122: Comparison of experimental and numerical results of wallettes at 800ºC.

5.3.2 Thermal response prediction of 3m walls at elevated temperatures

Based on the experimental and numerical investigations carried out on the masonry wallettes in fire, predicting the behaviour of 3m height masonry walls under the same conditions applied to the wallettes was another objective of this research. In this Section, the F.E. predicted thermal behaviour of the walls is only presented.

The same material properties used for modelling the masonry wallettes were also applied for the F.E. analyses in order to predict the behaviour of the 3m walls. The wall modelling was also subjected to the same target temperatures used in the experimental wallettes; however, they were only heated on one side to simulate standard fire resistance tests.

A typical graph showing the predicted thermal results of 3m walls is presented in Figure 123; four curves are generally shown. They are: one curve that measured the temperature inside the furnace (obtained from the wallette tests) and three more representing the temperature distribution at the cold and heated faces and at the centre of the wall.

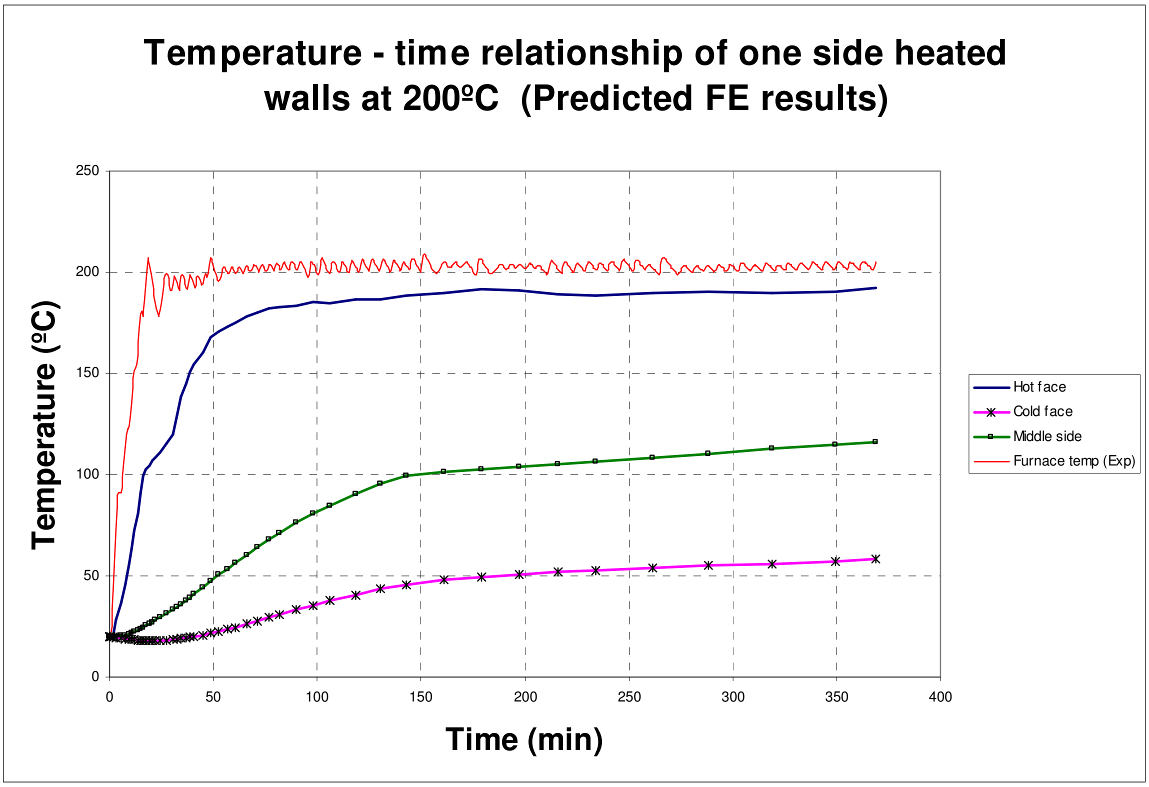


Figure 123: Predicted thermal behaviour of 3m walls at 200ºC.

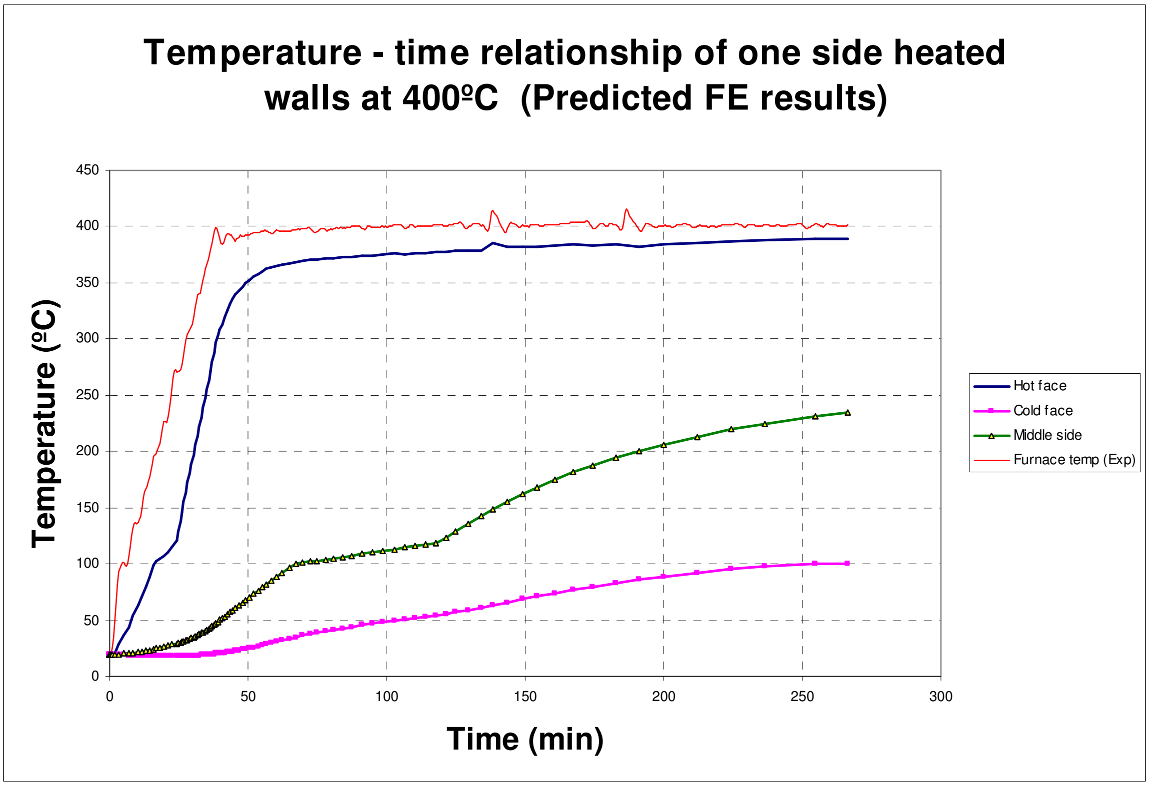


Figure 124: Predicted thermal behaviour of 3m walls at 400ºC.

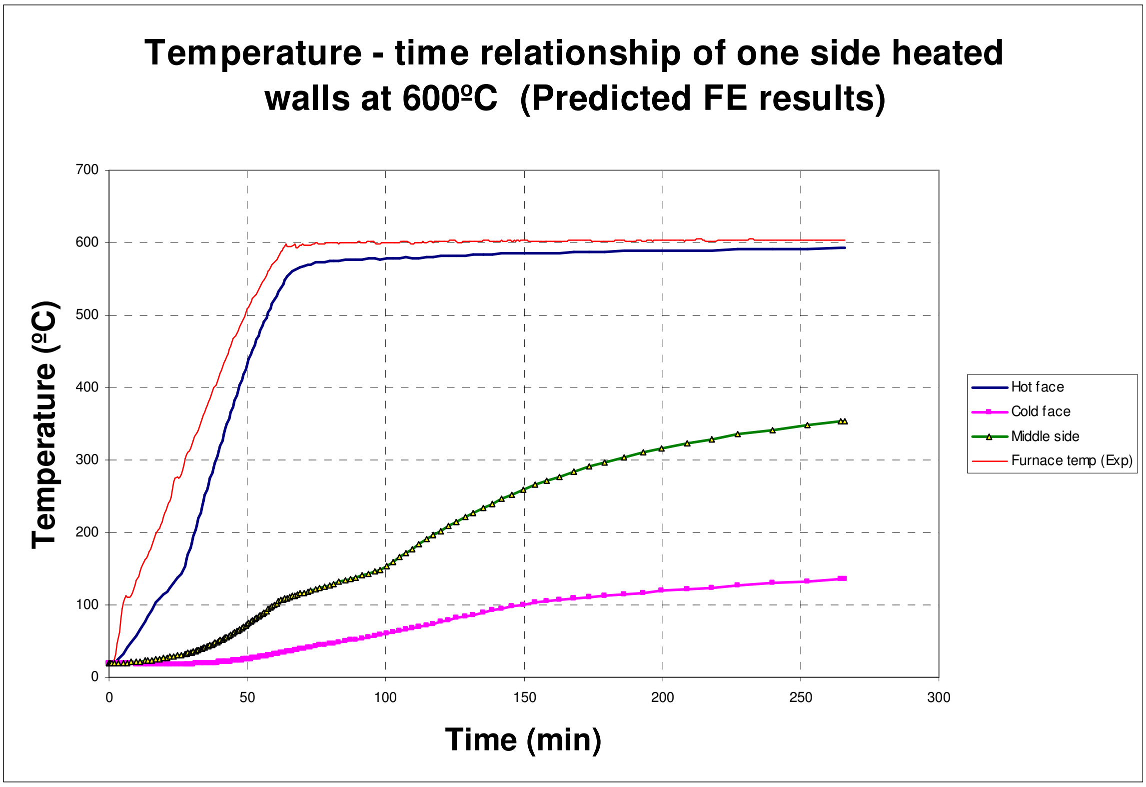


Figure 125: Predicted thermal behaviour of 3m walls at 600ºC.

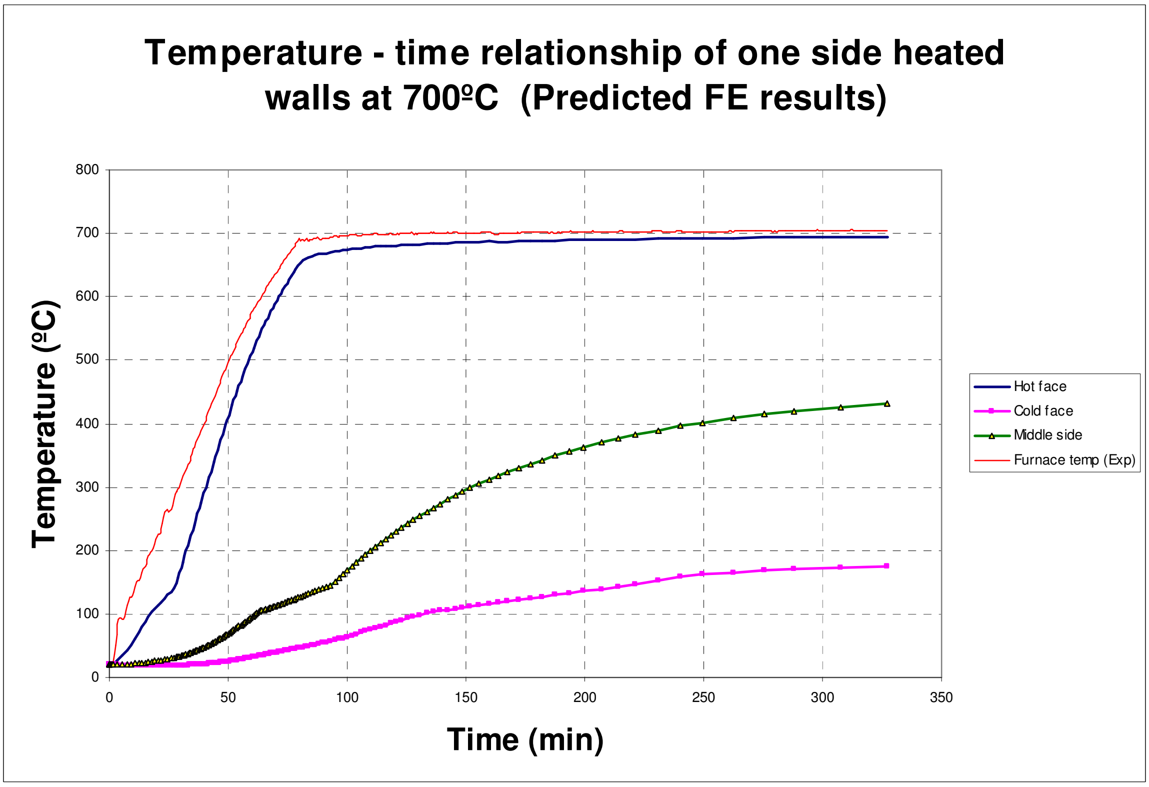


Figure 126: Predicted thermal behaviour of 3m walls at 700ºC.

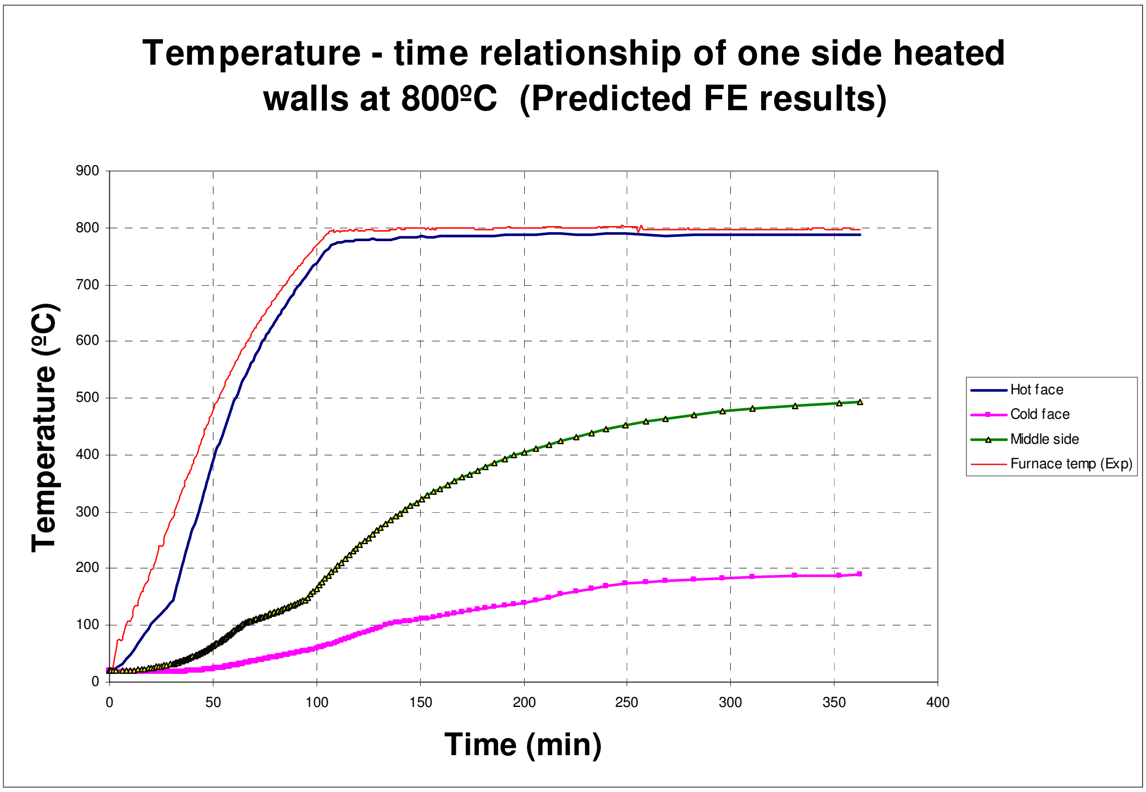


Figure 127: Predicted thermal behaviour of 3m walls at 800ºC.

The predicted thermal results of the one heated side big walls at 200ºC, 400ºC, 600ºC, 700ºC and 800ºC are shown in Figures 123 to 127 respectively.

According to the results, it can be observed that the curve (to measure the temperature in the face exposed) followed clearly the furnace temperature curve in the models exposed to higher temperatures than those to lower temperatures.

A distinctive plateau was exhibited at a similar temperature range which occurred in the experimental wallettes and simulated in the previous models.

It can also be seen that the maximum achieved temperature on the cold face of the models was approximately 25% of the target temperatures; however, this was different in the model exposed at 200ºC, in which, a roughly maximum temperature of 30% from this temperature was achieved in its cold face.

In Figure 123, it is observed the evident absence of a plateau in the curve measuring the temperature in the middle of the wall, although the appropriate property for this was used in the model. In contrast, a very pronounced plateau is observed in the same type of curve for the walls exposed at 400ºC. For higher temperature responses, the plateau was “softer”.

After the plateau range finished, it can be observed that the achieved parabola shape of all the curves at all temperatures, which differs from the almost linear shape of the same in the model at 200ºC.

5.3.3 Results from structural analysis of masonry wallettes

This information shows the mechanical response obtained by simulating the masonry wallettes with ABAQUS. The figures show the average curve obtained from the wallettes tested at elevated temperatures and each is compared with that obtained from the Finite Element Models.

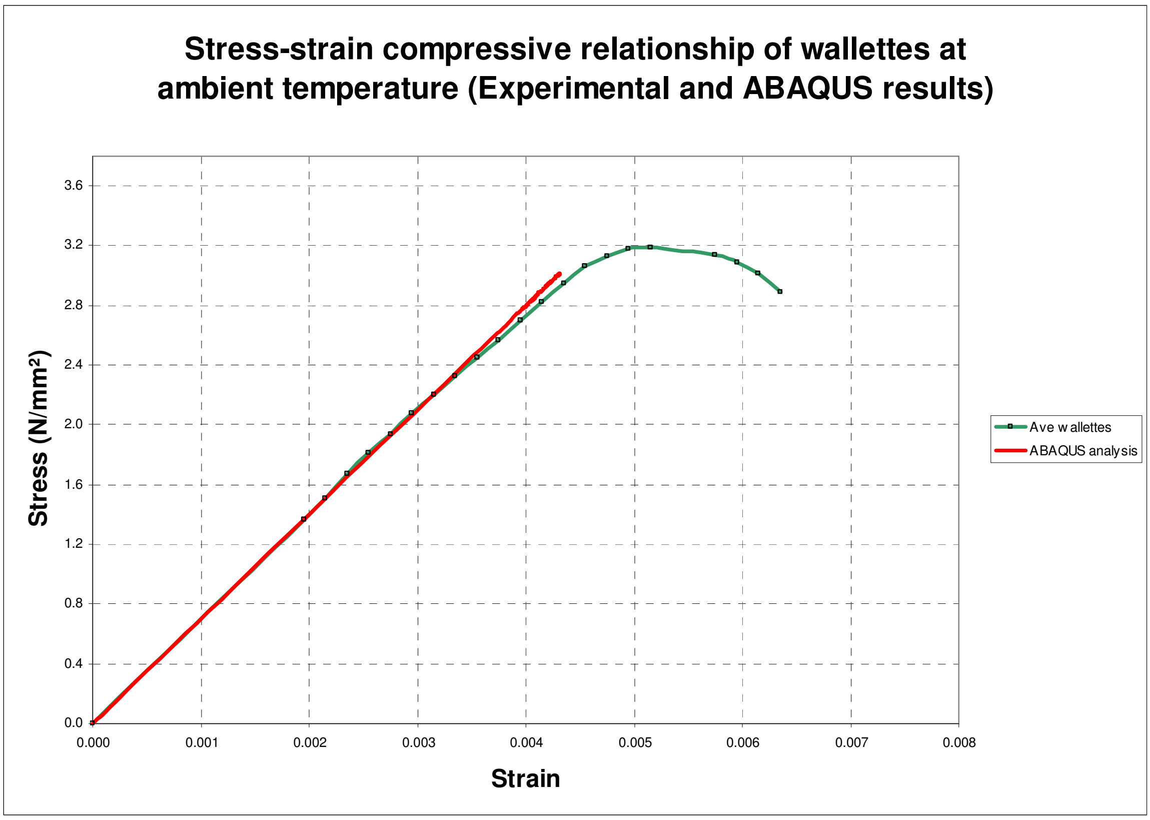


Figure 128: Comparison of the experimental compressive stress-strain relationship of the masonry wallettes and ABAQUS results at ambient temperature.

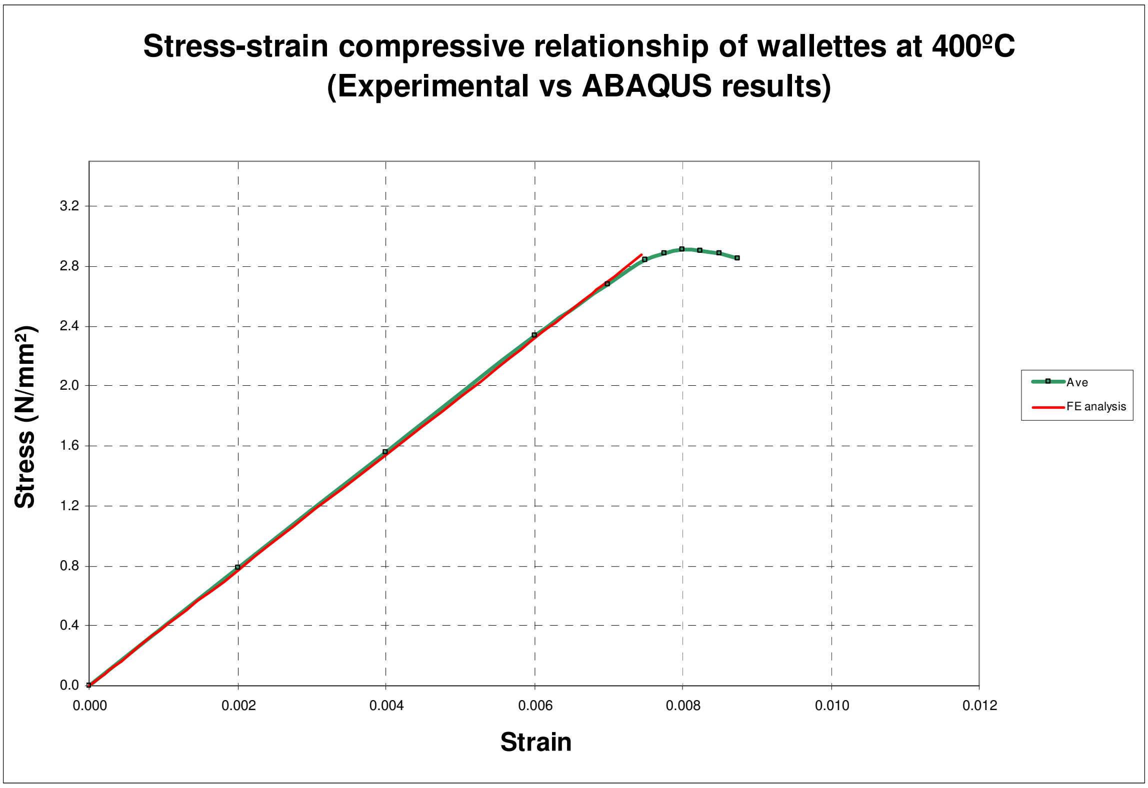


Figure 129: Comparison of the experimental compressive stress-strain relationship of the masonry wallettes and ABAQUS results at 400ºC.

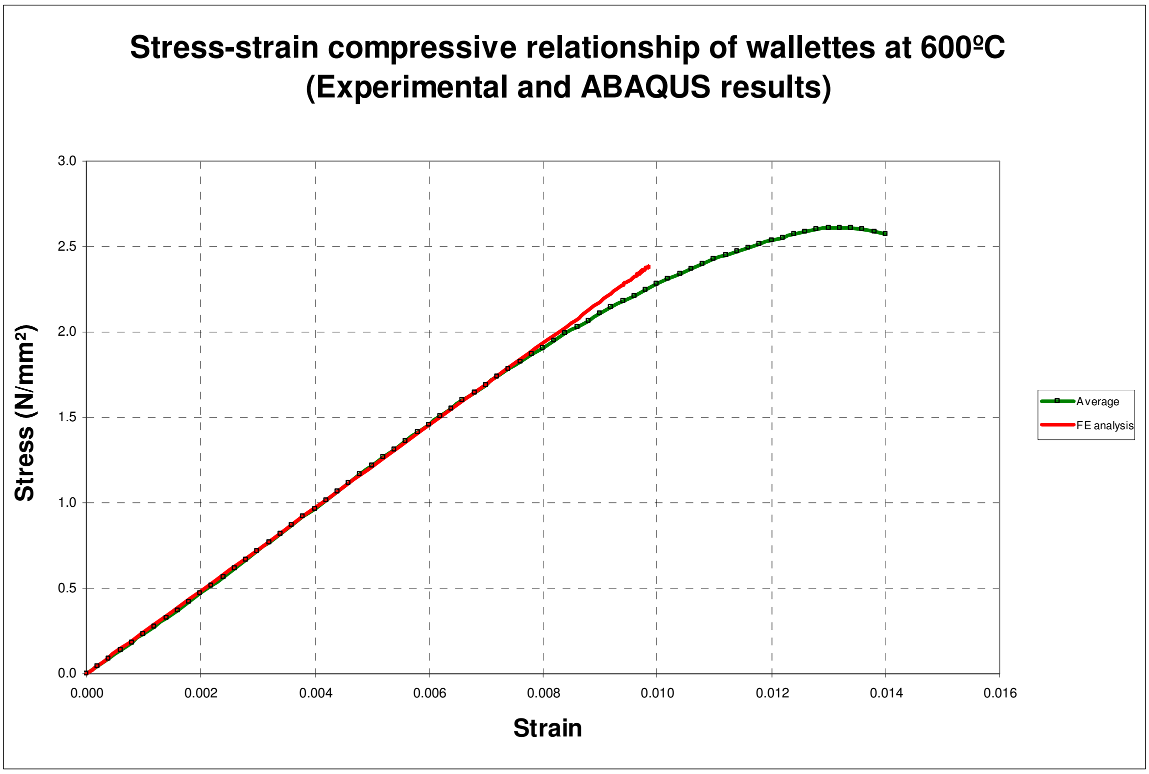


Figure 130: Comparison of the experimental compressive stress-strain relationship of the masonry wallettes and ABAQUS results at 600ºC.

In general, the structural response from the Finite Element models is in a good agreement with the experimental results. Figure 128 to 131 shows the comparison between the model and the test results. It is interesting to note that the results at 20ºC are in a good match until the maximum stress. However, the numerical response does not follow the same curve after failure.

At 400ºC the results show a good match up to the maximum stresses without significant difference. The result from ABAQUS matches well with the average curve from the wallettes heated and tested at 600ºC; the differences can be seen in the curve after the maximum stresses were achieved.

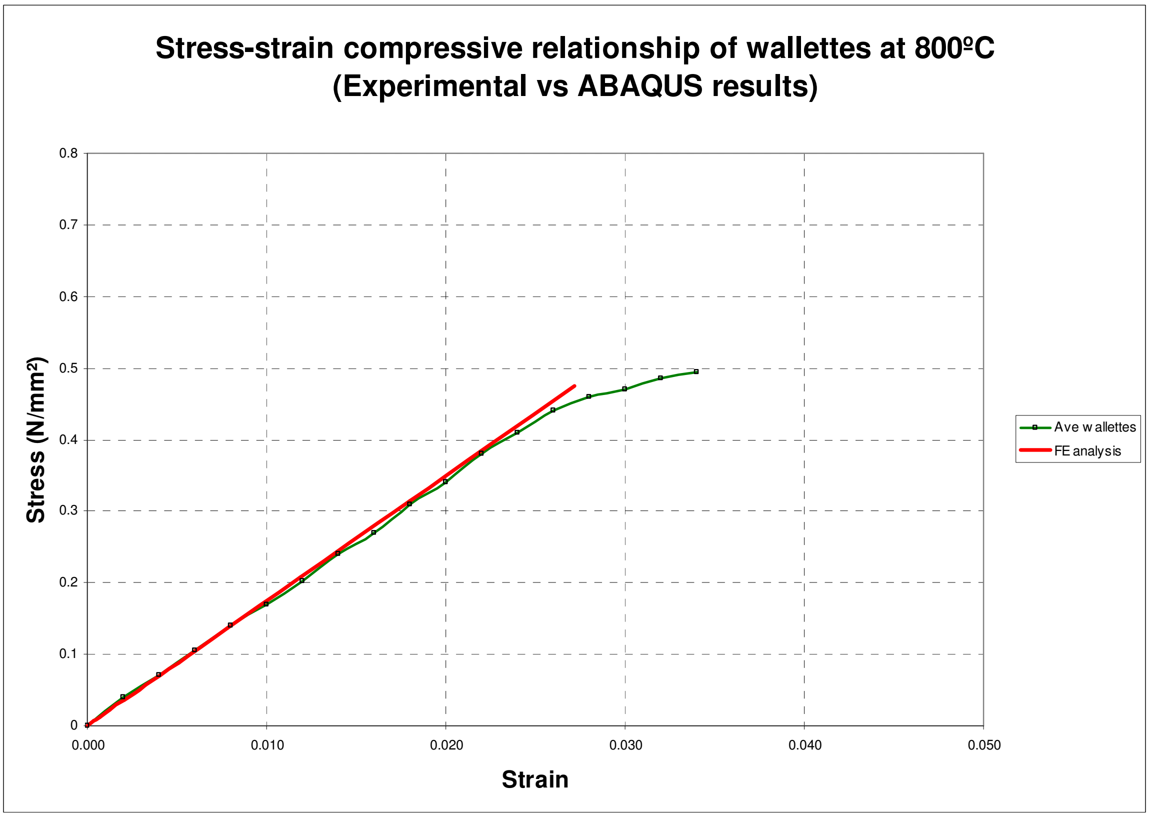


Figure 131: Comparison of the experimental compressive stress-strain relationship of the masonry wallettes and ABAQUS results at 800ºC.

The same tendency presented by the previous analyses of ABAQUS is also shown in the result of the model at 600ºC, in which, the response from 0 up to the maximum stress is quasi-linear with an evident variation in the curve post-failure. Finally, in Figure 131 is presented the comparison of the experimental average curve of the wallettes at 800ºC and the result from ABAQUS, it can be observed that there were some small variations along the linear part of the curves.

At 200ºC and 700ºC numerical analyses were not carried out due to the lack of the compressive stress-strain relationships of the blocks. At 200ºC the tested blocks were so damaged by the long heating period that the obtained compressive strength was considered lower than the expected. Meanwhile, the compressive strength at 700ºC was not obtained because the number of blocks provided to carry out these tests was insufficient.

5.3.4 Results from structural analysis of 3m walls

Predicting the behaviour of 3m walls by using the same properties from the experimental wallettes and the analyses was one of the most important issues of this work. However, because the structural analyses of the wallettes were the last phase for these studies due to last experimental results and limitations in time, this implied a slower development for the structural analyses of the wallettes and consequently the structural responses of the 3m walls was not completed.

Chapter 6

Conclusions

6.1 Introduction

This chapter talks about the conclusions, limitations, future work and general observations from the experimental work and Finite Element Models carried out for this thesis. They are related with the performance of the masonry wallettes exposed to different high temperatures.

This also comprises some findings and observations from the series of tests on individual lightweight concrete blocks and mortar specimens that were carried out to reproduce the identical behaviour from the components used for the wallettes.

The current investigation results could have a contribution to develop new techniques and to improve the existing similar ones in order to determine not only the different masonry properties in fire, but to extend it to other type of structures.

Finally, in this section, some parameters are outlined that were not investigated due to the time limit, but they are suggested to be carried out as further research.

6.2 Limitations of the present study

The investigations, presented here, were carried out with some limitations that are detailed as follows:

- The original plan included the determination of the basic mechanical properties of masonry at elevated temperatures, focused on tensile and compressive strengths. However, the investigations on the tensile strength were finally excluded owing to the lack of scientific information and some limitations in appropriate equipment to carry out the tests.

- Although there are lots of varieties of block shapes and materials on the market, the masonry investigations shown here were only carried out with solid concrete blocks made with lightweight aggregates. Therefore, the differences in behaviour with other materials and shapes under identical test conditions should be investigated.

- For mortar compressive tests at elevated temperatures, difficulties were experienced in finding equipment for carrying out the tests properly. For instance, there was no furnace with the characteristics to reproduce the identical thermal load for the mortar used in the wallettes and an adequate compressive machine to apply slow loading rates such as 0.03N/(mm^2*sec) [127].

- Eighteen mortar cubes were cast to determine the compressive strength at the same thermal conditions used in the experimental wallettes; additionally, eighteen mortar cylinders were prepared to obtain the modulus of elasticity. The same proportion and water/cement ratio were applied in the specimens. A test setup was also prepared and ready to start the test. Unfortunately, these tests were not carried out because the period programmed for the masonry investigations, reported here, concluded. Consequently, this affected the obtaining of data for the final results of the Finite Element models developed to simulate masonry in fire.

6.3 Conclusions

The information presented in this section contains the most important findings from each stage carried out for this study

6.3.1 Behaviour of masonry wallettes at elevated temperatures

Some of the main advantages of having tested small masonry specimens were:

-to facilitate their construction and easy transportation
-to use small testing machines
-to reduce final costs and consuming time
-to reproduce similar behaviour experienced in full sized walls

The most important conclusions can be summarized as follows:

- The masonry wallettes experienced a reduction in the compressive strength, which was approximately 9%, 19%, 60%, and 83% at 400ºC, 600ºC, 700ºC and 800ºC.
- As a consequence of the variation in the compressive strength of the wallettes, the modulus of elasticity was also decreased to the following levels: 33%, 40%, 65%, 89% and 98% at 200ºC, 400ºC, 600ºC, 700ºC and 800ºC respectively.
- The failure modes in the wallettes tested at ambient temperature were dominated by a combination of conical shear and large horizontal crackings.
- The wallettes heated and tested at 200ºC and over were characterized by diagonal cracking as the most distinctive failure.
- The phenomenon known as spalling occurred in the masonry wallettes tested at 400ºC and higher, being more intense at higher temperatures; the spalling induced the explosion of small aggregates from the surface of the specimens. Spalling was also featured by popping sounds which were heard at around 20-30 minutes after the beginning of the tests.

- Another result produced by heat was the thermal expansion, with a minor effect in those specimens heated at 200ºC and more severe in the wallettes exposed to 700ºC and 800ºC.
- The masonry wallettes also experienced a colour change produced by the exposure to elevated temperatures, which was less distinctive in the wallettes heated at 200ºC and more in those at 800ºC; this change varied from dark grey to almost white at the highest temperature.
- In the specimens mainly heated at 700ºC and 800ºC, the block material suffered of serious deterioration that resulted in melting some aggregates contained in the block material, one of these aggregates was glass.
- The phase change, liquid water into vapour, which was shown as a plateau occurred in all the wallettes heated at elevated temperatures. This plateau appeared around 100ºC and its duration varied slightly according to the target temperature.
- Based on the experimental results and general observations, it could be demonstrated that the use of the wallettes was an effective, safe and economical way to study the performance of masonry in fire.

6.3.2 Behaviour of lightweight concrete blocks with temperature

The main objective of having tested individual lightweight concrete blocks was to reproduce the identical behaviour of the blocks in the experimental wallettes in order to obtain data to incorporate it into Finite Element Models; the following observations and conclusions were found:

- The compressive strength was reduced at elevated temperatures; this variation was in the order of 28%, 27%, 18% and 65% at 200ºC, 400ºC, 600ºC and 800ºC.
- The compressive strength was unexpectedly reduced at 200ºC, this was attributed to the very long times taken to achieve the thermal balance in the blocks, which did not succeed and lasted around 28 hours compared to typically 8 hrs for other temperatures.
- As observed, the variation in the compressive strength of the blocks with temperature had an unexpected performance, especially in the blocks

tested at 600ºC. After this, the compressive strength was abruptly reduced to 800ºC.

- The stiffness of the lightweight concrete blocks was diminished with temperature; this decrease was around 46%, 55%, 62% and 92% at 200ºC, 400ºC, 600ºC and 800ºC.
- The same damage level caused by spalling in the wallette tests was resulted in the blocks tested individually. Although the same thermal conditions were applied in both tests, it was observed that the damage in the blocks was apparently less severe than in the wallettes, this could be explained due to a greater area exposed in the wallettes to elevated temperatures than in the blocks.
- The most common failure, occurred in the blocks tested at ambient and elevated temperatures, was shear splitting.
- Thermal expansion was observed to occur in the blocks heated at 700ºC and 800ºC.
- As occurred in the wallette tests, the blocks exposed to high temperatures had a change of colour which varied in the same level than that in the wallettes.
- A Plateau in the temperature data was also observed in the blocks heated at elevated temperatures, this occurred at approximately 110ºC. Its duration depended on the target temperatures.

6.3.3 Performance of mortar at elevated temperatures

The most important features of the mortar at elevated temperature are highlighted below. The conclusions are only based on the tensile capacity.

- The tensile strength of mortar was characterized by an unexpected reduction to 66% at 200ºC and 73% at 400ºC.
- The tensile capacity of mortar showed a decrease with an increase in the temperature. The maximum average loads ranged from 1390N to 380N for temperatures of 20ºC to 400ºC.

6.3.4 Finite Element Models

The conclusions from the Finite Element Models conducted to simulate the fire behaviour of masonry were as follow:

- In general, the results from the thermal analyses developed to model the temperature distribution of the masonry wallettes at different temperatures showed a good match with those obtained from the experiments.
- The thermal properties applied in the analyses and obtained from parametric studies to reproduce the behaviour of the components used in the experimental wallettes, allowed good results from the analyses.
- The radiative heat flux was estimated using a concrete value of 0.7.
- The convective coefficients assumed for the heated and unheated faces were 25W/m²K and 4W/m²K respectively.
- The thermal conductivity value for lightweight concrete blocks was taken as 0.33W/m²K for the analyses at 200ºC, 400ºC and 600ºC; meanwhile, a value of 0.32W/m²K was used for the modelling at 700ºC and 800ºC.
- In the case of the thermal conductivity value for mortar; 2.9W/m²K was taken for the analyses at 200ºC and it was reduced to 1.4W/m²K for the rest of the target temperatures.
- The structural responses from the models created to evaluate the mechanical properties of the experimental wallettes were in good match.
- The assumed values of the stress-strain relationship of the mortar in compression and in tension permitted good results from the analyses.
- Generally, the stress-strain compressive relationships of the blocks obtained experimentally at elevated temperatures were effectively applied to model the wallettes.
- Although the shear behaviour of mortar was not included in the structural phase of the Finite Element Models, the numerical results were in good agreement with those from the experiments. As demonstrated in the failure modes of the wallettes, the pattern was mostly dominated by block failure. Therefore, based on this assumption and to simplify the model, shear behaviour of mortar was not considered within the Finite Element Models.

6.3.5 Generalities

- It was found that most of the actual international fire design masonry codes do not include concise calculation models for determination of fire resistance periods.
- The Table 2.2 in chapter 2 reflects the need to increase research on the behaviour of masonry in fire in order to complement the actual study. It also enhances the absolutely absence of regulations on masonry structures in fire for Latin America.

6.4 Recommendations for further study

In order to complement the study of masonry in fire, there are some areas which were not covered with the investigations presented here. It is therefore suggested to research on the following:

- To create a database, it is suggested to investigate the fire behaviour of wallettes using a bigger range of block strengths, materials and shapes. Moreover, to include different block aspect, for instance, laid flat. This should be done applying the same test conditions reported here.
- To obtain the tensile strength of masonry in fire, it should use an important variety of block shapes and materials.
- For further masonry tests based on steady state conditions, it is recommended to take periods of 1hr or 3hrs after having achieved the apparent thermal equilibrium in order to ensure that even both top and bottom faces can be heated at the same level than the other parts of the specimens.
- In order to complement the study of masonry in fire, it should include series of mortar and unit tests at different high temperatures to have a better understanding on the masonry components.
- Based on the thermo-mechanical responses from the computer models on masonry wallettes, the work should be extended to complete the structural modelling for 3m walls in order to predict their behaviour at the same temperatures than those applied in the experimental wallettes.

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APPENDIX A – Material composition

Table A.1 contains the chemical composition of the Portland cement used in the investigations presented.

Table A.1 Cement components

Substance	Unit	Percentage
Sulphate	SO_3	2.5 to 3.5
Chloride	Cl	Less than 0.05
Alkali	Eq Na_2O	0.4 to 0.75
Tricalcium silicate	C_3S	45.0 to 60.0
Dicalcium silicate	C_2S	15.0 to 25.0
Tricalcium Aluminate	C_3A	7.0 to 12.0
Tetracalcium Aluminoferrite	C_4AF	6.0 to 10.0

Additionally, Table A.2 shows the most important chemical components of the dental plaster used to attach the thermocouples to the surface of the wallettes and to align the bottom faces of them. This dental plaster has been employed as a high strength material for producing removal dental pieces with a high precision

Table A.2 Dental plaster composition

<table>
<tr><th>Chemical composition</th><th>Chemical names</th><th>Dry compressive strength (MPa)</th><th>Water mix ratio (by weight)</th><th>Final setting time (min)</th></tr>
<tr><td rowspan="3">$CaSO_4 1/2H_2O$</td><td>Calcium</td><td rowspan="3">55</td><td rowspan="3">100:30</td><td rowspan="3">13</td></tr>
<tr><td>Sulphate</td></tr>
<tr><td>Hemihydrate</td></tr>
</table>

Table A.2 summarizes the name of the lightweight aggregates contained in the construction of the blocks used for these experimental investigations.

Table A.3 Lightweight aggregates used for blocks

Block lightweight Aggregates
Furnace bottom ash from power stations
Expanded clay
Lime stone
Recycled glass
Portland cement

APPENDIX B – Experimental data of the wallettes

Experimental data from the masonry wallettes tested at ambient temperature.

Wallette 3

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
0.0	0.000	14.8	0.305	30.4	0.506	39.1	0.633	49.5	0.784	61.9	0.955
0.3	0.014	15.6	0.313	30.8	0.509	39.5	0.637	49.7	0.788	62.3	0.960
0.4	0.022	15.7	0.320	30.8	0.512	39.8	0.640	50.2	0.794	62.7	0.966
0.7	0.029	16.3	0.328	30.9	0.514	40.1	0.647	50.9	0.799	63.3	0.971
0.9	0.034	17.1	0.338	31.3	0.519	40.6	0.650	51.2	0.804	63.8	0.977
0.9	0.042	17.4	0.341	31.8	0.523	41.0	0.655	51.4	0.808	64.5	0.985
1.6	0.055	17.5	0.346	32.4	0.528	40.9	0.658	52.0	0.812	64.6	0.990
2.1	0.064	18.4	0.355	32.5	0.531	41.2	0.662	51.6	0.815	65.0	0.998
1.8	0.069	18.6	0.362	32.7	0.534	41.4	0.663	51.8	0.817	65.9	1.004
2.5	0.080	19.3	0.369	32.8	0.536	41.5	0.667	52.5	0.822	66.4	1.012
3.0	0.095	19.5	0.374	33.3	0.540	41.8	0.671	52.8	0.828	66.6	1.017
3.7	0.103	19.4	0.378	33.2	0.542	42.0	0.677	52.9	0.832	67.0	1.024
3.6	0.113	20.2	0.383	33.3	0.545	42.5	0.680	53.7	0.838	67.0	1.026
4.3	0.117	20.9	0.393	33.6	0.548	42.7	0.686	54.2	0.842	67.8	1.035
4.9	0.132	21.6	0.397	33.8	0.552	42.9	0.689	54.2	0.849	68.3	1.040
5.4	0.141	21.8	0.405	34.2	0.555	43.3	0.694	54.6	0.852	68.6	1.046
5.5	0.150	22.4	0.410	34.0	0.559	43.7	0.698	54.7	0.857	69.2	1.052
5.8	0.157	22.5	0.413	34.5	0.561	43.8	0.702	54.9	0.861	69.7	1.060
6.6	0.168	23.1	0.418	34.8	0.566	44.0	0.705	55.5	0.866	69.7	1.064
6.8	0.175	23.5	0.424	35.3	0.569	44.5	0.708	55.6	0.867	70.4	1.069
7.0	0.183	23.7	0.428	35.2	0.573	44.5	0.710	56.0	0.872	70.3	1.072
7.3	0.186	24.3	0.433	35.5	0.577	44.5	0.713	56.3	0.877	70.7	1.077
7.9	0.198	24.8	0.440	35.9	0.581	44.5	0.715	56.9	0.882	70.8	1.080
8.1	0.203	25.5	0.447	36.2	0.585	44.8	0.721	57.0	0.886	71.4	1.089
8.7	0.212	26.0	0.452	36.9	0.590	45.3	0.723	57.6	0.892	72.1	1.094
9.2	0.221	26.4	0.457	36.4	0.594	46.0	0.727	57.9	0.897	72.4	1.102
9.9	0.229	26.4	0.461	36.8	0.597	45.7	0.731	58.3	0.903	72.5	1.105
10.0	0.233	26.8	0.464	37.4	0.599	46.5	0.736	58.6	0.908	73.2	1.113
10.6	0.241	27.1	0.467	36.9	0.603	46.8	0.741	58.9	0.911	73.7	1.117
11.1	0.248	27.4	0.472	37.6	0.606	47.2	0.749	59.2	0.914	74.3	1.124
11.9	0.259	28.0	0.480	37.9	0.610	47.8	0.753	59.1	0.918	74.3	1.127
11.6	0.262	28.4	0.485	38.0	0.612	47.7	0.759	59.7	0.921	74.8	1.132
12.3	0.274	28.7	0.487	38.7	0.615	48.6	0.763	60.3	0.929	74.8	1.137
13.1	0.281	29.1	0.492	38.5	0.619	48.6	0.766	60.7	0.933	75.1	1.142
13.5	0.291	29.4	0.495	38.7	0.624	48.7	0.769	61.0	0.939	76.0	1.148
13.9	0.294	29.7	0.500	38.9	0.627	49.3	0.776	61.1	0.942	76.1	1.155
14.0	0.299	30.0	0.502	39.0	0.630	49.3	0.780	61.5	0.949	76.7	1.160

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
77.0	1.166	93.9	1.394	109.6	1.615	125.0	1.837	139.9	2.064	154.4	2.318
77.4	1.171	94.1	1.398	110.0	1.619	125.3	1.841	140.3	2.070	154.6	2.322
77.6	1.176	94.3	1.404	110.3	1.625	125.6	1.846	140.7	2.078	155.2	2.332
78.1	1.179	94.6	1.407	110.4	1.629	125.6	1.849	141.2	2.083	155.9	2.339
78.5	1.184	94.9	1.411	110.5	1.634	125.9	1.855	140.9	2.087	156.4	2.347
79.1	1.189	94.9	1.416	111.1	1.638	126.2	1.858	141.6	2.094	156.6	2.353
78.9	1.192	95.7	1.424	111.4	1.645	126.9	1.866	141.9	2.101	156.7	2.360
79.5	1.199	96.2	1.428	111.8	1.650	127.5	1.870	142.2	2.105	156.7	2.365
80.1	1.206	96.5	1.435	112.6	1.658	127.6	1.876	142.5	2.110	156.9	2.370
80.3	1.211	96.8	1.440	113.0	1.663	127.9	1.882	142.8	2.115	156.8	2.375
80.8	1.218	97.6	1.445	113.3	1.668	128.4	1.890	143.5	2.122	157.3	2.381
81.5	1.225	97.5	1.449	113.4	1.672	128.8	1.894	143.7	2.127	157.9	2.387
81.9	1.231	97.4	1.453	113.6	1.677	129.1	1.900	143.9	2.134	158.5	2.396
82.0	1.235	97.8	1.456	113.9	1.680	129.2	1.904	144.1	2.138	158.5	2.402
82.5	1.240	98.3	1.461	114.1	1.685	129.6	1.909	144.3	2.144	159.4	2.409
82.6	1.243	98.5	1.465	114.1	1.687	129.7	1.911	144.7	2.148	159.2	2.414
83.3	1.249	99.2	1.468	114.1	1.691	130.5	1.919	144.9	2.152	159.3	2.419
83.4	1.255	99.1	1.471	115.2	1.697	130.9	1.924	145.3	2.159	159.2	2.423
83.8	1.263	99.6	1.480	115.8	1.703	131.2	1.930	145.8	2.167	159.3	2.429
84.2	1.268	100.1	1.484	116.0	1.709	131.0	1.934	146.4	2.172	159.4	2.431
84.8	1.274	100.7	1.490	116.2	1.715	132.0	1.941	146.7	2.180	159.8	2.440
85.3	1.279	100.8	1.495	117.0	1.719	132.3	1.947	147.1	2.186	160.4	2.445
86.0	1.285	101.6	1.501	117.0	1.725	132.7	1.954	147.5	2.192	160.9	2.453
85.9	1.289	101.9	1.504	117.1	1.728	133.1	1.958	147.9	2.196	161.2	2.458
86.6	1.295	102.0	1.509	117.6	1.733	133.1	1.963	147.7	2.203	161.1	2.465
86.6	1.299	101.8	1.512	117.7	1.736	133.5	1.967	148.2	2.207	161.8	2.470
87.1	1.305	102.0	1.517	117.8	1.740	133.7	1.971	148.5	2.214	161.9	2.476
87.4	1.311	102.1	1.519	118.0	1.743	133.8	1.975	149.2	2.221	162.2	2.480
88.2	1.317	102.7	1.526	118.8	1.751	134.4	1.983	149.6	2.229	162.6	2.486
88.3	1.321	103.4	1.531	119.3	1.757	134.7	1.987	150.3	2.236	162.4	2.490
89.0	1.329	104.1	1.539	119.9	1.764	135.4	1.994	150.3	2.243	163.0	2.496
89.1	1.333	104.7	1.545	120.5	1.770	135.5	1.998	150.1	2.248	163.4	2.503
89.6	1.340	105.3	1.554	120.7	1.777	136.3	2.005	151.0	2.254	163.8	2.511
90.3	1.343	105.4	1.559	121.5	1.782	136.6	2.011	151.1	2.258	164.4	2.517
90.4	1.348	105.9	1.563	121.9	1.788	136.7	2.017	151.1	2.263	164.2	2.524
90.5	1.353	106.3	1.569	122.0	1.792	137.0	2.022	151.4	2.266	164.6	2.529
90.7	1.355	106.7	1.575	122.4	1.798	137.7	2.028	151.8	2.276	165.4	2.537
91.2	1.363	106.6	1.580	122.5	1.801	137.7	2.032	152.8	2.283	165.1	2.542
92.0	1.371	107.6	1.588	123.7	1.812	138.3	2.040	153.2	2.292	165.4	2.548
92.7	1.375	108.1	1.595	124.2	1.817	138.6	2.045	153.4	2.298	165.4	2.551
93.0	1.382	108.7	1.602	124.5	1.825	139.2	2.052	154.2	2.305	166.3	2.562
93.1	1.387	109.2	1.607	124.7	1.830	139.7	2.057	154.0	2.312	166.5	2.568

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
166.8	2.576	179.9	2.892	188.3	3.286
167.3	2.583	179.5	2.900	188.3	3.296
167.7	2.590	179.8	2.906	188.3	3.309
168.0	2.597	180.1	2.914	188.4	3.319
167.9	2.602	180.6	2.923	187.9	3.328
167.9	2.607	180.9	2.934	188.2	3.340
168.0	2.612	181.5	2.947	188.5	3.357
168.8	2.620	181.7	2.957	188.9	3.369
169.6	2.630	181.7	2.963	188.7	3.385
170.1	2.637	181.8	2.972	188.7	3.395
170.1	2.645	181.7	2.976	188.5	3.410
170.3	2.651	182.6	2.988	188.0	3.418
170.5	2.657	182.9	2.996	188.5	3.434
170.4	2.661	183.3	3.006	188.4	3.448
170.7	2.667	183.3	3.014	188.6	3.467
170.9	2.672	183.7	3.024	188.8	3.478
171.2	2.682	183.8	3.030	188.2	3.494
172.1	2.689	183.1	3.036	187.7	3.503
172.4	2.698	183.5	3.044	187.6	3.523
172.8	2.704	184.1	3.057	188.0	3.537
173.0	2.712	184.7	3.065	187.9	3.555
173.2	2.718	184.8	3.077	187.4	3.569
172.8	2.723	184.7	3.085	186.6	3.586
173.4	2.730	184.5	3.094	186.6	3.597
174.2	2.741	185.3	3.100	185.4	3.612
175.0	2.749	184.7	3.107	185.9	3.628
174.9	2.758	185.2	3.117	185.3	3.648
175.0	2.764	185.6	3.130	185.0	3.663
174.9	2.772	186.3	3.139	184.8	3.684
175.3	2.776	185.9	3.150	184.3	3.700
175.3	2.782	186.4	3.157	183.1	3.720
175.5	2.787	186.3	3.166	183.2	3.739
176.2	2.798	186.1	3.170	181.7	3.770
176.7	2.806	186.6	3.183	180.3	3.789
176.9	2.817	186.8	3.192	178.1	3.817
177.0	2.824	187.0	3.204	176.1	3.838
177.6	2.836	187.3	3.213	173.6	3.873
177.6	2.842	187.2	3.223		
177.6	2.849	187.3	3.230		
178.0	2.854	187.0	3.240		
178.5	2.866	187.0	3.248		
178.9	2.873	186.8	3.255		
179.0	2.884	187.8	3.269		

Wallette 20

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
0.0	0.000	40.5	1.415	56.4	1.745	63.4	1.885	69.7	2.000	76.8	2.130
0.4	0.170	41.3	1.425	56.5	1.755	63.4	1.890	69.6	2.000	76.7	2.130
0.7	0.200	41.6	1.435	57.1	1.765	63.6	1.890	70.2	2.000	76.8	2.140
2.7	0.230	41.6	1.435	56.7	1.765	64.0	1.900	70.5	2.010	77.6	2.140
4.8	0.290	41.7	1.440	57.2	1.770	63.7	1.900	70.5	2.020	77.9	2.145
6.7	0.380	42.1	1.440	57.7	1.775	64.2	1.900	71.1	2.020	78.0	2.150
9.3	0.470	41.8	1.450	58.0	1.775	63.9	1.905	70.7	2.025	78.0	2.155
12.3	0.605	42.2	1.455	57.7	1.780	64.5	1.910	71.4	2.030	78.6	2.160
12.5	0.635	42.5	1.460	57.6	1.780	64.9	1.910	71.2	2.025	78.9	2.160
16.3	0.725	43.5	1.465	58.5	1.785	64.7	1.910	71.4	2.035	78.8	2.160
18.0	0.790	44.0	1.480	58.2	1.790	64.9	1.915	71.6	2.035	78.6	2.165
19.8	0.850	45.5	1.515	58.5	1.790	64.7	1.915	72.3	2.040	79.4	2.180
20.9	0.875	46.3	1.530	58.4	1.790	65.3	1.915	71.9	2.045	79.6	2.180
22.3	0.915	46.4	1.535	59.0	1.800	65.4	1.925	72.6	2.050	79.9	2.190
23.1	0.950	47.0	1.550	58.8	1.800	65.4	1.925	72.4	2.055	80.0	2.185
25.2	1.015	47.3	1.555	59.2	1.805	65.7	1.930	72.6	2.060	80.1	2.190
26.8	1.045	47.5	1.565	59.4	1.810	65.6	1.930	72.6	2.060	80.0	2.195
28.4	1.085	48.2	1.575	59.4	1.810	65.8	1.930	72.9	2.060	80.8	2.195
29.4	1.115	48.3	1.585	59.7	1.820	65.6	1.935	73.3	2.065	80.8	2.205
30.1	1.135	49.5	1.610	59.9	1.820	66.6	1.940	73.7	2.075	81.0	2.210
30.6	1.155	49.8	1.610	59.9	1.820	66.2	1.940	73.5	2.070	81.4	2.215
31.0	1.170	49.7	1.615	59.7	1.820	66.3	1.945	73.7	2.075	82.2	2.220
32.0	1.190	50.2	1.625	60.4	1.825	66.9	1.950	74.1	2.080	82.0	2.225
33.6	1.220	50.5	1.625	60.7	1.835	67.7	1.955	74.2	2.085	82.6	2.225
34.0	1.250	51.0	1.635	61.2	1.835	67.4	1.965	74.4	2.090	82.8	2.230
34.6	1.255	50.9	1.645	61.0	1.840	67.7	1.960	74.1	2.090	82.7	2.235
35.1	1.270	51.1	1.655	61.1	1.845	67.7	1.965	75.0	2.090	83.0	2.235
35.5	1.290	51.8	1.660	61.6	1.845	68.0	1.965	74.6	2.095	83.4	2.245
36.5	1.310	52.2	1.670	61.7	1.845	67.9	1.965	74.9	2.100	83.6	2.245
36.9	1.320	52.1	1.670	61.9	1.855	68.0	1.965	74.3	2.100	83.5	2.245
37.1	1.335	53.0	1.680	61.8	1.855	68.2	1.975	74.8	2.095	83.6	2.255
38.6	1.355	53.0	1.680	61.6	1.860	68.5	1.980	74.5	2.095	84.3	2.255
39.2	1.365	53.2	1.690	62.0	1.860	68.2	1.975	74.9	2.100	84.0	2.260
39.3	1.375	53.2	1.695	62.4	1.865	68.3	1.980	75.1	2.110	84.4	2.260
39.4	1.385	55.0	1.715	62.5	1.865	68.7	1.985	75.7	2.110	84.6	2.265
39.7	1.390	55.1	1.725	62.6	1.875	68.7	1.985	75.9	2.115	84.3	2.270
39.9	1.395	55.3	1.730	62.5	1.875	69.0	1.985	76.0	2.120	84.6	2.275
40.2	1.405	55.6	1.735	62.7	1.875	69.0	1.990	75.9	2.120	84.8	2.275
40.4	1.410	55.8	1.745	63.1	1.880	69.3	2.000	76.0	2.120	84.9	2.280
40.6	1.415	56.6	1.745	63.1	1.880	69.7	2.000	75.9	2.120	85.0	2.280

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
85.2	2.280	96.9	2.455	122.5	2.835	157.0	3.355	187.4	3.870	213.5	4.440
85.4	2.285	97.1	2.465	123.0	2.855	158.3	3.370	188.2	3.885	213.8	4.455
86.3	2.290	97.6	2.470	122.8	2.855	158.9	3.380	189.1	3.900	214.2	4.460
85.9	2.290	97.6	2.475	124.1	2.860	159.4	3.390	189.4	3.915	215.3	4.475
86.1	2.300	98.4	2.480	125.8	2.875	160.2	3.405	190.2	3.920	215.1	4.490
86.5	2.300	98.4	2.480	125.8	2.880	161.5	3.420	191.2	3.935	215.1	4.495
86.8	2.300	99.3	2.490	126.7	2.890	162.5	3.435	191.7	3.945	216.8	4.525
86.8	2.310	99.8	2.500	127.0	2.900	163.0	3.445	192.8	3.965	217.9	4.535
86.8	2.310	100.8	2.510	127.6	2.910	164.2	3.460	192.8	3.970	218.1	4.555
87.1	2.310	101.0	2.515	129.5	2.930	165.1	3.475	193.8	3.990	218.1	4.565
87.4	2.320	102.0	2.530	130.4	2.940	166.6	3.495	194.3	4.000	219.7	4.595
88.1	2.320	102.5	2.530	131.5	2.955	167.8	3.515	195.1	4.020	220.0	4.615
87.7	2.330	102.8	2.540	131.6	2.965	168.8	3.535	195.1	4.025	220.0	4.625
88.7	2.330	103.6	2.550	133.1	2.985	169.8	3.545	196.0	4.040	219.8	4.645
89.0	2.330	103.5	2.555	133.8	2.995	170.6	3.565	197.3	4.055	220.9	4.675
88.9	2.340	104.6	2.565	135.2	3.010	170.8	3.575	197.9	4.070	222.1	4.695
89.1	2.340	105.2	2.575	135.7	3.020	170.9	3.580	198.4	4.080	222.2	4.715
89.2	2.340	105.7	2.585	136.1	3.035	171.8	3.595	199.0	4.095	221.5	4.735
89.7	2.350	106.7	2.595	138.4	3.050	173.3	3.610	200.0	4.115	223.0	4.765
89.2	2.350	107.2	2.605	139.4	3.075	173.7	3.625	201.3	4.130	222.8	4.785
89.6	2.350	107.5	2.615	140.3	3.085	174.6	3.635	202.3	4.145	222.4	4.805
90.3	2.360	108.2	2.625	141.1	3.105	174.9	3.645	202.0	4.155	221.4	4.820
90.4	2.365	109.5	2.640	142.5	3.115	175.7	3.665	203.3	4.175	222.3	4.850
90.9	2.365	110.8	2.655	143.4	3.130	176.1	3.670	204.2	4.190	222.6	4.870
90.5	2.365	111.0	2.665	143.9	3.145	176.9	3.690	204.6	4.205	222.8	4.895
90.7	2.370	111.8	2.680	143.8	3.155	177.8	3.700	205.1	4.220	222.8	4.915
91.4	2.375	113.0	2.690	145.0	3.165	178.5	3.710	205.5	4.235	223.4	4.950
92.0	2.380	113.6	2.700	146.3	3.185	177.9	3.720	206.9	4.255	223.8	4.975
92.0	2.385	113.8	2.710	147.6	3.195	179.2	3.730	208.6	4.270	224.0	4.990
92.5	2.390	114.7	2.720	147.7	3.205	180.1	3.745	208.6	4.285	224.3	5.005
92.8	2.395	115.3	2.730	148.5	3.215	180.8	3.755	208.1	4.295	224.2	5.030
93.0	2.400	115.9	2.740	150.2	3.235	181.4	3.765	209.4	4.310	224.0	5.060
92.9	2.400	116.4	2.755	150.6	3.245	181.5	3.780	210.2	4.325	225.0	5.100
93.7	2.410	117.4	2.765	151.5	3.260	182.3	3.790	211.0	4.340	224.4	5.125
93.7	2.415	117.9	2.775	152.0	3.270	182.7	3.800	211.4	4.355	225.0	5.180
94.5	2.415	118.5	2.785	153.0	3.285	182.9	3.810	211.5	4.365	224.4	5.215
95.1	2.420	118.7	2.785	153.9	3.295	183.8	3.820	211.2	4.375	224.7	5.260
94.7	2.425	119.8	2.795	154.4	3.305	184.1	3.830	211.8	4.395	224.0	5.310
96.0	2.430	120.6	2.810	155.3	3.315	184.5	3.835	212.1	4.405	221.8	5.360
96.6	2.445	121.0	2.820	155.4	3.325	185.0	3.845	212.8	4.415	221.3	5.410
96.3	2.450	121.6	2.825	155.7	3.335	186.3	3.865	213.2	4.425	219.4	5.475

Experimental data from the masonry wallettes tested at 200ºC.

Wallette 5

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
0.0	0.129	43.2	1.091	55.4	1.405	69.6	1.708	84.0	2.015	100.3	2.318
2.2	0.169	43.5	1.101	55.8	1.416	70.3	1.715	84.1	2.017	100.7	2.328
3.4	0.239	44.1	1.111	56.3	1.421	70.4	1.725	84.9	2.025	100.9	2.335
5.6	0.254	44.6	1.120	56.2	1.424	70.8	1.736	85.3	2.037	101.2	2.342
5.4	0.308	44.9	1.128	56.9	1.431	71.2	1.747	85.8	2.047	102.0	2.353
7.7	0.378	45.5	1.140	57.1	1.440	71.3	1.753	86.4	2.056	102.5	2.364
9.8	0.429	45.6	1.148	57.6	1.448	71.9	1.760	86.8	2.064	103.5	2.380
11.8	0.465	45.7	1.152	58.0	1.459	72.5	1.771	87.4	2.074	103.8	2.390
13.2	0.519	46.5	1.160	58.3	1.468	73.0	1.782	87.8	2.081	104.5	2.400
15.6	0.568	46.7	1.168	58.9	1.479	73.2	1.790	87.6	2.084	104.6	2.404
17.8	0.608	47.0	1.178	59.2	1.485	73.8	1.800	88.1	2.094	105.5	2.416
19.8	0.628	47.5	1.187	59.2	1.488	74.6	1.809	88.6	2.103	106.1	2.426
20.8	0.669	47.8	1.195	59.5	1.495	74.9	1.817	89.3	2.111	107.1	2.440
22.7	0.726	47.9	1.202	60.0	1.507	74.6	1.819	89.5	2.120	107.6	2.452
25.6	0.771	48.5	1.210	60.8	1.516	75.5	1.830	90.2	2.129	107.9	2.464
27.7	0.783	48.3	1.213	61.3	1.525	76.0	1.840	90.9	2.138	107.7	2.476
28.5	0.825	48.3	1.217	61.5	1.536	76.2	1.851	91.3	2.145	107.8	2.477
30.5	0.867	48.6	1.226	62.3	1.548	76.7	1.859	91.1	2.149	108.6	2.486
32.8	0.901	49.8	1.237	62.3	1.552	77.2	1.867	91.4	2.157	108.8	2.497
34.2	0.909	50.2	1.247	62.4	1.559	77.5	1.875	91.9	2.167	109.6	2.507
34.4	0.922	50.7	1.257	63.1	1.568	77.7	1.884	92.3	2.174	110.7	2.517
35.3	0.941	50.8	1.265	63.5	1.579	77.6	1.886	92.8	2.184	111.4	2.527
36.1	0.981	51.0	1.274	63.9	1.588	78.3	1.898	93.2	2.192	111.2	2.534
38.7	1.005	51.1	1.278	64.6	1.597	79.0	1.908	93.6	2.201	111.5	2.539
39.8	1.018	51.4	1.284	64.8	1.607	79.7	1.921	94.0	2.205	112.2	2.549
40.3	1.021	52.3	1.293	65.2	1.615	80.1	1.928	93.5	2.208	112.9	2.558
40.2	1.030	52.7	1.303	65.1	1.618	80.4	1.938	94.4	2.216	113.3	2.568
40.5	1.034	52.9	1.310	65.3	1.624	80.8	1.946	95.1	2.225	113.7	2.576
40.7	1.040	52.7	1.320	66.0	1.633	80.9	1.952	95.7	2.232	114.2	2.585
40.7	1.046	53.6	1.331	66.6	1.645	81.2	1.957	96.1	2.243	115.0	2.595
41.1	1.052	53.2	1.367	67.1	1.652	81.8	1.965	96.4	2.252	114.7	2.601
41.4	1.058	53.0	1.371	67.6	1.661	82.3	1.974	97.3	2.265	115.5	2.610
41.8	1.066	53.2	1.374	67.7	1.669	82.8	1.984	97.3	2.270	116.3	2.623
42.1	1.073	53.9	1.378	68.3	1.678	83.1	1.990	97.3	2.274	117.1	2.636
42.4	1.080	54.2	1.380	67.9	1.685	83.2	1.997	98.3	2.285	117.9	2.650
43.0	1.082	54.5	1.387	68.4	1.686	83.5	2.003	98.6	2.297	118.6	2.659
42.6	1.082	55.3	1.397	68.9	1.697	83.8	2.010	99.7	2.307	118.6	2.665

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
119.1	2.675	141.4	3.085	165.1	3.531	184.1	3.949	199.5	4.386	210.3	4.919
119.5	2.686	142.1	3.096	165.3	3.543	183.8	3.953	200.2	4.398	209.7	4.931
120.2	2.694	142.1	3.106	165.7	3.551	184.3	3.963	200.4	4.411	210.9	4.948
120.8	2.704	142.0	3.112	165.4	3.558	185.1	3.974	200.7	4.425	210.8	4.969
121.4	2.715	142.7	3.120	166.2	3.570	185.7	3.984	201.3	4.438	211.1	4.986
121.7	2.724	143.4	3.132	167.4	3.585	186.3	3.993	201.1	4.447	210.6	5.007
122.3	2.729	144.5	3.146	168.0	3.594	186.9	4.003	201.4	4.458		
122.0	2.733	144.9	3.158	168.5	3.604	186.6	4.013	201.4	4.471		
122.6	2.742	145.3	3.166	169.2	3.615	186.8	4.018	202.7	4.484		
123.6	2.756	145.6	3.173	169.1	3.622	187.7	4.032	202.9	4.500		
124.2	2.766	146.1	3.182	169.9	3.633	188.3	4.045	202.8	4.514		
124.9	2.779	147.3	3.197	170.5	3.645	189.0	4.060	202.9	4.524		
125.7	2.791	147.5	3.207	171.2	3.657	189.4	4.069	203.4	4.538		
125.5	2.798	148.5	3.218	171.9	3.670	189.9	4.081	203.5	4.551		
126.3	2.808	148.7	3.228	172.2	3.679	189.4	4.085	204.1	4.560		
127.2	2.821	149.0	3.237	171.8	3.685	190.7	4.100	204.3	4.571		
127.8	2.834	148.9	3.238	172.8	3.696	191.0	4.108	204.4	4.581		
128.6	2.846	149.8	3.250	173.4	3.709	191.4	4.120	204.6	4.591		
128.9	2.854	150.6	3.263	174.1	3.719	191.7	4.129	204.3	4.596		
128.6	2.859	151.4	3.278	174.6	3.731	192.3	4.141	204.6	4.608		
129.6	2.870	152.1	3.289	174.9	3.744	191.8	4.152	205.1	4.617		
130.6	2.883	152.7	3.298	175.0	3.753	191.8	4.157	205.3	4.631		
131.2	2.893	152.4	3.302	175.9	3.765	192.3	4.169	206.0	4.641		
131.8	2.905	153.5	3.319	176.6	3.780	193.3	4.181	206.6	4.656		
132.4	2.916	154.6	3.333	177.0	3.792	193.3	4.190	206.7	4.666		
132.2	2.920	155.4	3.347	177.3	3.802	194.2	4.201	206.2	4.676		
132.9	2.928	156.1	3.359	177.8	3.810	194.2	4.211	207.2	4.689		
133.4	2.941	155.5	3.365	177.8	3.818	194.5	4.220	207.7	4.710		
134.4	2.953	155.9	3.373	177.5	3.821	194.1	4.224	208.4	4.725		
134.9	2.966	156.5	3.384	178.5	3.835	195.0	4.237	208.8	4.741		
135.4	2.974	157.4	3.396	179.4	3.845	195.7	4.248	208.0	4.748		
135.7	2.982	158.2	3.410	180.0	3.856	196.3	4.264	208.6	4.762		
135.7	2.986	158.7	3.419	180.2	3.866	196.7	4.274	209.2	4.780		
136.2	2.999	159.2	3.427	180.6	3.875	196.9	4.286	209.4	4.800		
136.8	3.009	159.1	3.433	181.2	3.882	197.0	4.292	209.5	4.813		
137.8	3.021	160.3	3.449	180.8	3.886	197.3	4.308	209.4	4.827		
138.3	3.031	161.3	3.462	181.3	3.895	197.8	4.319	208.9	4.836		
138.7	3.042	162.3	3.476	181.9	3.907	198.2	4.332	209.4	4.854		
138.8	3.047	162.4	3.488	182.6	3.915	198.8	4.344	209.6	4.866		
139.2	3.054	162.6	3.494	182.8	3.925	199.1	4.357	209.9	4.880		
139.8	3.062	163.1	3.504	183.5	3.932	199.1	4.366	209.9	4.893		
140.6	3.076	163.9	3.517	183.5	3.943	199.1	4.374	210.3	4.909		

Wallette 6

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
0.0	0.000	51.7	1.159	70.1	1.550	84.6	1.831	96.9	2.059	112.0	2.321
0.4	0.021	52.2	1.173	70.2	1.557	84.9	1.836	97.9	2.067	112.3	2.328
0.9	0.071	52.3	1.182	70.7	1.564	85.2	1.842	98.5	2.072	112.6	2.334
1.4	0.098	52.7	1.191	71.0	1.570	85.6	1.848	98.3	2.079	112.8	2.338
2.6	0.174	53.3	1.202	71.3	1.577	85.7	1.855	98.6	2.085	113.3	2.344
4.2	0.223	55.6	1.238	71.7	1.584	86.2	1.861	99.2	2.093	113.6	2.351
5.2	0.262	56.0	1.253	72.0	1.592	86.1	1.865	99.6	2.097	114.0	2.358
6.8	0.317	56.0	1.260	72.6	1.600	87.1	1.872	100.0	2.104	114.5	2.364
9.9	0.393	56.5	1.268	72.6	1.603	87.4	1.881	100.3	2.112	115.0	2.371
10.8	0.418	56.4	1.272	72.9	1.612	87.6	1.885	100.8	2.119	115.4	2.377
11.8	0.446	56.9	1.281	73.5	1.620	88.0	1.890	101.2	2.124	115.3	2.382
13.8	0.483	57.3	1.289	74.2	1.629	88.2	1.897	101.7	2.134	115.8	2.389
15.9	0.526	57.6	1.297	74.2	1.635	88.9	1.904	102.5	2.143	116.4	2.396
18.4	0.577	57.8	1.306	74.9	1.643	88.7	1.909	102.3	2.153	116.8	2.404
18.3	0.579	58.8	1.317	75.0	1.650	88.9	1.916	103.3	2.160	116.8	2.412
20.9	0.623	59.2	1.325	75.6	1.658	89.9	1.923	103.5	2.167	117.7	2.419
23.0	0.663	59.3	1.332	75.9	1.664	90.0	1.928	103.5	2.173	118.2	2.426
25.8	0.706	59.6	1.337	76.1	1.668	90.1	1.934	104.5	2.182	118.3	2.433
27.3	0.730	60.1	1.348	76.2	1.675	90.7	1.941	104.0	2.186	118.6	2.441
27.5	0.735	60.6	1.358	77.3	1.685	91.0	1.948	104.8	2.192	118.6	2.443
28.8	0.757	61.1	1.366	77.0	1.692	91.6	1.956	105.2	2.201	119.4	2.449
30.9	0.789	61.3	1.375	77.8	1.701	91.8	1.961	105.9	2.207	119.4	2.455
32.8	0.816	62.2	1.387	78.3	1.710	92.3	1.969	106.0	2.212	119.8	2.460
34.4	0.840	62.9	1.400	78.8	1.722	92.7	1.974	106.4	2.218	120.2	2.466
35.5	0.859	62.7	1.405	79.2	1.729	92.7	1.981	106.7	2.225	120.6	2.473
36.5	0.876	63.6	1.418	79.4	1.735	93.1	1.987	107.0	2.232	120.9	2.479
37.9	0.899	64.8	1.434	79.5	1.739	93.3	1.992	107.5	2.237	121.0	2.485
40.1	0.929	65.3	1.448	80.0	1.747	93.2	1.994	107.9	2.245	121.6	2.490
41.6	0.955	65.9	1.459	80.4	1.754	93.8	2.002	107.7	2.250	121.9	2.495
42.6	0.976	66.3	1.468	80.4	1.761	93.8	2.006	108.4	2.258	122.1	2.501
42.4	0.981	66.4	1.475	81.1	1.768	94.6	2.010	108.8	2.264	122.3	2.505
44.2	1.006	67.0	1.484	81.6	1.777	94.6	2.016	109.5	2.272	122.5	2.509
46.0	1.034	67.1	1.494	82.0	1.784	94.9	2.023	109.6	2.279	123.2	2.518
47.5	1.067	67.8	1.504	82.8	1.791	94.9	2.027	110.2	2.288	123.9	2.526
48.3	1.088	68.8	1.516	83.2	1.798	95.5	2.033	110.1	2.292	124.7	2.537
48.1	1.094	69.0	1.523	82.8	1.801	96.1	2.039	110.7	2.298	125.2	2.544
48.7	1.105	69.3	1.531	83.5	1.811	96.5	2.045	111.2	2.305	125.5	2.552
49.0	1.118	69.6	1.536	83.7	1.818	97.0	2.050	111.5	2.312	125.8	2.557
50.4	1.134	69.7	1.545	84.1	1.824	96.7	2.055	111.2	2.314	125.6	2.562

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
126.0	2.567	142.8	2.858	161.7	3.198	182.2	3.628	196.0	4.015	202.7	4.553
125.8	2.570	143.4	2.867	162.2	3.208	182.0	3.631	196.4	4.025	202.9	4.572
126.7	2.579	143.9	2.876	162.4	3.214	182.4	3.641	196.5	4.036	202.6	4.592
127.0	2.587	143.9	2.882	162.5	3.220	182.8	3.651	196.4	4.047	201.8	4.605
127.4	2.593	144.3	2.889	163.6	3.230	183.5	3.662	196.0	4.051	202.2	4.625
128.1	2.599	144.5	2.894	164.3	3.242	184.0	3.671	197.2	4.065	201.5	4.648
128.2	2.605	145.6	2.907	165.0	3.252	184.5	3.680	198.0	4.082	200.1	4.669
128.6	2.612	146.2	2.915	165.7	3.263	184.6	3.691	198.6	4.097	200.0	4.695
129.2	2.618	146.5	2.926	166.0	3.273	184.4	3.700	198.9	4.108	198.1	4.737
129.6	2.624	147.3	2.936	166.0	3.282	184.6	3.707	199.0	4.119	191.4	4.799
129.5	2.630	148.1	2.949	166.9	3.293	185.4	3.720	198.4	4.127		
130.1	2.635	148.1	2.954	167.8	3.306	185.7	3.730	199.3	4.141		
130.5	2.643	148.7	2.961	168.4	3.318	186.7	3.743	199.7	4.153		
131.1	2.652	148.8	2.969	169.0	3.334	187.2	3.751	200.0	4.164		
132.0	2.661	149.6	2.979	169.2	3.342	187.4	3.760	200.1	4.176		
132.8	2.672	150.4	2.986	169.5	3.351	187.5	3.768	200.5	4.189		
133.2	2.680	150.7	2.995	170.2	3.361	187.5	3.776	201.0	4.199		
133.5	2.689	151.2	3.004	171.0	3.375	188.0	3.786	200.2	4.207		
133.9	2.695	151.3	3.014	171.3	3.385	188.9	3.796	201.3	4.223		
133.9	2.705	151.7	3.020	172.1	3.396	189.7	3.809	201.7	4.239		
134.4	2.712	151.9	3.025	172.5	3.408	190.4	3.822	201.9	4.251		
135.0	2.719	152.3	3.033	173.1	3.418	190.7	3.830	202.0	4.263		
135.3	2.727	153.0	3.041	173.3	3.424	190.1	3.836	202.2	4.277		
135.8	2.736	153.2	3.047	174.0	3.442	190.3	3.847	201.9	4.289		
136.3	2.742	153.7	3.055	175.0	3.461	191.3	3.855	202.2	4.303		
136.4	2.748	153.9	3.061	175.5	3.471	191.3	3.863	203.0	4.317		
136.7	2.754	154.3	3.070	175.6	3.479	191.9	3.874	202.7	4.331		
136.8	2.761	154.7	3.076	176.3	3.489	192.2	3.884	202.8	4.346		
136.7	2.763	155.3	3.082	175.9	3.496	192.6	3.896	203.1	4.358		
137.6	2.770	155.1	3.087	176.6	3.508	192.2	3.900	202.7	4.368		
138.0	2.777	156.1	3.097	177.2	3.516	192.6	3.911	203.3	4.384		
138.3	2.785	156.4	3.105	178.1	3.526	193.0	3.920	203.8	4.405		
138.8	2.791	157.3	3.116	178.3	3.536	193.2	3.930	204.1	4.420		
139.4	2.799	158.0	3.125	179.0	3.548	193.6	3.938	203.6	4.435		
139.7	2.806	158.1	3.134	179.1	3.556	194.1	3.948	203.9	4.451		
140.2	2.815	158.5	3.142	179.3	3.562	194.3	3.957	202.9	4.464		
140.6	2.819	158.6	3.149	179.6	3.572	194.6	3.968	203.2	4.476		
140.9	2.825	159.2	3.155	180.0	3.584	194.3	3.974	203.2	4.490		
140.9	2.830	160.1	3.168	180.5	3.593	194.3	3.981	203.7	4.507		
141.8	2.841	160.6	3.178	181.5	3.605	195.1	3.992	203.7	4.534		
142.1	2.849	161.4	3.189	181.9	3.616	196.1	4.006	203.2	4.542		

Wallette 7

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
0.0	0.000	44.1	0.925	64.3	1.310	79.1	1.712	95.6	2.034	110.2	2.337
0.6	0.047	44.7	0.934	64.4	1.318	79.3	1.723	95.8	2.040	111.0	2.347
1.1	0.075	45.5	0.943	64.8	1.327	79.9	1.734	96.0	2.047	111.7	2.356
2.1	0.123	46.7	0.964	65.3	1.338	80.9	1.745	96.6	2.056	112.5	2.366
3.3	0.166	47.0	0.974	65.6	1.345	81.1	1.758	97.2	2.064	112.5	2.372
3.9	0.185	47.2	0.981	65.9	1.353	81.6	1.765	98.0	2.073	113.1	2.379
5.3	0.224	48.3	0.996	66.5	1.362	81.6	1.767	98.4	2.083	112.6	2.382
7.4	0.271	49.7	1.017	66.9	1.375	82.8	1.780	98.6	2.093	113.7	2.395
9.3	0.309	50.2	1.028	66.9	1.379	83.2	1.788	98.6	2.112	114.3	2.402
9.9	0.324	50.7	1.039	67.6	1.388	83.7	1.799	98.8	2.115	114.6	2.412
11.1	0.348	51.2	1.048	68.4	1.401	84.2	1.809	98.7	2.116	115.3	2.422
12.7	0.382	51.2	1.055	68.6	1.413	85.1	1.821	99.6	2.126	115.6	2.435
14.9	0.411	51.5	1.062	69.2	1.423	84.9	1.832	99.9	2.132	116.4	2.443
17.1	0.456	52.0	1.071	69.8	1.435	85.4	1.836	100.6	2.140	116.3	2.449
17.3	0.476	52.6	1.079	70.1	1.444	84.9	1.839	100.8	2.147	116.8	2.458
19.3	0.514	53.1	1.090	70.2	1.451	85.8	1.849	101.5	2.157	117.4	2.471
20.2	0.527	53.4	1.098	70.9	1.460	86.0	1.855	101.8	2.164	118.2	2.480
21.1	0.546	54.0	1.107	71.4	1.471	86.6	1.860	102.3	2.171	118.7	2.492
22.7	0.573	54.2	1.115	72.0	1.481	86.8	1.869	102.5	2.177	119.4	2.502
25.0	0.615	54.6	1.122	72.1	1.491	87.7	1.878	102.4	2.180	119.7	2.512
25.1	0.621	55.1	1.130	72.7	1.500	87.7	1.885	102.4	2.183	119.9	2.517
26.7	0.645	55.8	1.138	73.2	1.509	88.3	1.892	102.9	2.189	119.8	2.525
28.5	0.672	56.0	1.145	73.5	1.517	88.5	1.898	103.5	2.196	120.3	2.535
29.9	0.703	56.5	1.154	73.4	1.522	88.9	1.901	103.9	2.204	120.9	2.545
31.4	0.727	56.8	1.161	74.4	1.532	88.9	1.912	104.3	2.211	121.5	2.552
32.6	0.744	57.3	1.168	74.7	1.592	89.5	1.918	104.6	2.218	121.9	2.561
32.7	0.748	57.3	1.174	72.1	1.599	89.9	1.925	105.2	2.225	122.3	2.570
34.3	0.771	58.0	1.186	72.8	1.607	90.2	1.933	105.6	2.234	122.8	2.580
34.9	0.780	58.7	1.195	73.0	1.623	90.9	1.939	106.0	2.238	122.9	2.586
36.3	0.802	59.1	1.206	73.4	1.626	90.8	1.959	105.8	2.244	122.7	2.591
37.8	0.821	59.8	1.217	73.6	1.629	91.1	1.960	106.3	2.250	123.7	2.603
39.2	0.841	60.2	1.229	73.8	1.633	91.6	1.969	107.3	2.262	124.4	2.615
39.1	0.842	60.7	1.236	74.4	1.639	92.1	1.974	107.7	2.270	125.2	2.624
40.2	0.861	60.7	1.243	75.2	1.649	91.7	1.976	108.1	2.278	125.9	2.636
41.1	0.873	61.1	1.250	75.7	1.660	92.5	1.985	108.6	2.287	126.2	2.647
41.7	0.885	61.7	1.262	76.4	1.669	93.5	1.995	108.6	2.312	125.9	2.657
42.2	0.891	62.2	1.271	76.6	1.676	93.9	2.002	108.9	2.313	126.3	2.662
43.0	0.900	62.7	1.282	77.3	1.684	94.5	2.011	109.2	2.316	127.1	2.673
43.1	0.909	63.4	1.293	78.0	1.694	94.9	2.020	109.3	2.320	127.5	2.683
43.1	0.914	63.9	1.304	78.0	1.705	95.4	2.029	109.8	2.330	128.2	2.696

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
128.8	2.704	147.0	3.106	164.7	3.532	183.3	4.070				
129.6	2.714	147.7	3.117	165.3	3.543	182.9	4.081				
129.6	2.724	148.0	3.126	165.7	3.552	184.2	4.099				
129.3	2.731	147.9	3.137	165.3	3.559	184.6	4.117				
130.1	2.740	148.0	3.142	166.2	3.570	185.1	4.133				
131.0	2.752	148.8	3.156	166.8	3.583	185.4	4.152				
131.6	2.762	149.1	3.166	167.6	3.594	185.1	4.159				
132.2	2.774	149.5	3.177	167.8	3.606	185.6	4.176				
132.4	2.783	150.4	3.189	168.5	3.617	186.3	4.195				
132.5	2.791	150.8	3.201	168.8	3.629	186.9	4.214				
132.5	2.796	151.1	3.210	168.6	3.639	186.7	4.227				
133.4	2.808	150.9	3.214	169.7	3.655	187.2	4.239				
133.8	2.816	151.2	3.225	170.2	3.665	187.1	4.255				
134.7	2.826	151.9	3.235	170.4	3.678	187.6	4.274				
134.9	2.838	152.7	3.244	171.1	3.691	187.7	4.288				
135.3	2.849	152.8	3.255	171.1	3.702	188.0	4.304				
135.6	2.856	153.6	3.269	171.2	3.710	187.9	4.319				
135.7	2.863	154.4	3.281	172.3	3.725	187.9	4.334				
135.9	2.870	153.9	3.286	172.9	3.742	188.5	4.351				
135.8	2.897	154.9	3.298	173.9	3.758	189.1	4.370				
136.5	2.902	155.3	3.310	173.9	3.769	188.9	4.390				
137.2	2.911	156.1	3.323	174.1	3.776	188.5	4.413				
138.0	2.921	156.7	3.334	174.3	3.790	187.7	4.426				
138.2	2.932	156.9	3.344	175.3	3.807	187.7	4.453				
138.8	2.940	157.1	3.352	175.5	3.817	186.3	4.482				
138.4	2.945	157.9	3.366	176.3	3.830						
139.5	2.954	158.7	3.377	176.6	3.844						
140.0	2.964	159.2	3.388	176.2	3.854						
140.1	2.972	159.6	3.398	177.2	3.869						
140.9	2.981	159.7	3.411	178.0	3.886						
141.3	2.991	159.7	3.417	178.5	3.901						
141.9	3.002	159.5	3.423	178.9	3.916						
142.0	3.008	160.1	3.433	178.8	3.926						
142.3	3.015	160.9	3.445	179.1	3.939						
143.2	3.027	160.9	3.452	180.5	3.956						
143.8	3.039	162.0	3.463	180.9	3.974						
144.2	3.050	162.4	3.474	181.1	3.986						
145.0	3.060	162.8	3.484	181.1	3.999						
145.0	3.069	162.6	3.489	181.1	4.009						
144.9	3.075	162.6	3.499	182.4	4.030						
145.8	3.085	163.5	3.510	182.9	4.043						
146.1	3.094	164.3	3.523	182.9	4.057						

Experimental data from the masonry wallettes tested at 400ºC.

Wallette 9

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
0.0	0.000	28.2	1.106	39.0	1.504	46.5	1.820	57.0	2.220	68.8	2.671
0.8	0.002	29.2	1.123	39.1	1.513	46.9	1.831	57.2	2.232	68.9	2.677
0.9	0.010	29.5	1.139	39.5	1.520	47.0	1.833	57.5	2.245	68.8	2.687
1.2	0.044	29.7	1.154	39.6	1.524	47.3	1.844	57.4	2.254	69.4	2.699
1.8	0.094	29.8	1.158	40.0	1.534	47.5	1.855	58.0	2.267	69.8	2.708
2.4	0.117	30.4	1.177	39.7	1.542	47.9	1.866	58.3	2.279	70.2	2.720
3.0	0.150	30.6	1.189	40.4	1.551	48.0	1.875	58.8	2.293	70.4	2.732
3.4	0.186	31.1	1.199	40.5	1.557	48.4	1.884	59.4	2.308	71.1	2.748
4.5	0.243	31.5	1.210	40.3	1.564	48.3	1.895	59.7	2.326	71.2	2.759
5.5	0.274	32.5	1.236	40.6	1.571	49.0	1.907	59.8	2.336	71.6	2.771
5.6	0.288	32.8	1.251	40.9	1.579	49.4	1.914	60.2	2.349	71.6	2.779
6.4	0.321	33.8	1.274	41.0	1.587	49.6	1.925	60.6	2.359	72.0	2.790
7.0	0.359	33.9	1.288	41.3	1.596	49.4	1.933	60.5	2.367	72.3	2.798
7.9	0.394	34.2	1.297	41.6	1.603	49.7	1.940	60.7	2.377	72.6	2.810
8.6	0.429	34.9	1.319	42.1	1.615	49.8	1.954	61.5	2.389	73.1	2.820
9.8	0.466	35.0	1.331	42.0	1.621	50.2	1.966	61.5	2.402	73.4	2.832
10.8	0.509	35.2	1.339	42.0	1.624	50.6	1.978	61.8	2.418	73.9	2.843
11.0	0.523	35.7	1.348	42.4	1.633	51.3	1.994	62.3	2.432	74.2	2.858
11.8	0.557	35.4	1.356	42.1	1.643	51.5	2.004	62.9	2.444	74.4	2.870
13.2	0.594	35.7	1.366	42.5	1.649	51.7	2.016	63.1	2.456	74.9	2.880
13.7	0.625	36.0	1.375	42.7	1.655	52.1	2.029	63.0	2.465	74.7	2.883
15.0	0.660	36.0	1.384	42.8	1.663	52.3	2.041	63.6	2.477	75.4	2.900
16.0	0.701	36.5	1.393	43.0	1.671	52.4	2.047	64.3	2.491	76.0	2.914
17.6	0.752	36.6	1.404	43.3	1.678	52.7	2.062	64.1	2.503	76.4	2.931
17.9	0.773	37.0	1.411	43.7	1.688	52.8	2.073	64.6	2.516	76.7	2.944
18.7	0.797	37.0	1.415	43.8	1.700	53.3	2.086	64.9	2.526	77.3	2.958
20.0	0.838	37.2	1.421	43.9	1.710	53.6	2.095	65.3	2.541	77.9	2.974
21.1	0.870	37.4	1.432	44.1	1.719	53.8	2.106	66.0	2.554	77.6	2.982
22.1	0.907	37.4	1.438	44.2	1.726	54.4	2.117	66.2	2.568	78.2	2.993
22.9	0.931	37.7	1.446	45.0	1.738	54.7	2.132	66.0	2.573	78.5	3.007
24.0	0.959	37.9	1.452	45.2	1.752	54.9	2.144	66.5	2.584	79.2	3.020
24.6	0.987	38.0	1.461	45.5	1.759	54.7	2.150	66.9	2.598	79.6	3.035
25.1	0.994	38.2	1.467	45.7	1.769	55.1	2.160	67.1	2.612	79.9	3.048
26.0	1.025	38.4	1.475	45.7	1.781	55.4	2.172	67.4	2.622	80.4	3.062
26.3	1.047	38.4	1.481	45.9	1.793	55.7	2.180	68.2	2.636	80.5	3.074
27.0	1.061	38.7	1.490	46.3	1.800	55.7	2.190	68.4	2.649	80.6	3.081
27.5	1.086	39.0	1.496	46.6	1.810	56.5	2.203	68.8	2.664	81.1	3.089

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
81.2	3.117	98.7	3.710	118.6	4.390	139.4	5.148	159.7	5.917	177.3	6.726
81.7	3.135	99.2	3.723	119.2	4.411	139.1	5.154	159.5	5.925	177.9	6.745
82.3	3.159	99.5	3.736	120.2	4.433	140.3	5.179	160.5	5.954	178.5	6.764
82.9	3.182	99.5	3.743	120.8	4.448	141.4	5.199	161.7	5.973	179.1	6.788
83.5	3.204	100.3	3.762	121.1	4.468	141.9	5.223	162.3	5.994	179.6	6.811
83.8	3.220	101.0	3.776	121.7	4.490	142.4	5.240	162.6	6.015	179.4	6.826
83.7	3.230	101.9	3.792	121.6	4.503	142.5	5.255	162.7	6.032	179.5	6.840
83.9	3.243	102.5	3.810	122.7	4.523	142.0	5.264	163.0	6.048	180.1	6.858
85.0	3.261	102.6	3.826	123.1	4.549	143.0	5.284	163.8	6.074	180.8	6.876
85.4	3.276	102.6	3.833	123.7	4.569	143.6	5.301	164.3	6.096	181.4	6.894
85.8	3.294	103.0	3.843	124.4	4.590	144.3	5.319	164.7	6.118	181.5	6.916
86.3	3.308	103.7	3.859	124.8	4.603	144.4	5.337	165.1	6.132	182.0	6.936
86.9	3.322	104.3	3.879	124.7	4.616	145.2	5.353	164.7	6.147	181.6	6.952
87.0	3.333	104.8	3.892	124.8	4.629	145.2	5.366	165.7	6.168	182.4	6.976
87.4	3.343	105.4	3.907	125.9	4.653	145.0	5.374	166.5	6.192	182.8	7.001
88.0	3.356	105.6	3.920	126.5	4.669	146.2	5.393	166.8	6.211	183.5	7.026
88.1	3.368	105.9	3.930	127.4	4.687	146.7	5.417	167.4	6.230	184.0	7.054
88.4	3.380	106.4	3.942	127.6	4.704	147.2	5.432	167.9	6.250	183.2	7.069
89.0	3.395	107.0	3.957	127.6	4.720	148.0	5.450	167.8	6.263	183.7	7.093
89.7	3.409	107.7	3.975	128.1	4.733	148.3	5.469	168.5	6.285	184.3	7.122
89.9	3.423	108.3	3.994	129.1	4.757	147.9	5.480	169.7	6.313	184.7	7.153
90.1	3.436	108.9	4.007	129.7	4.779	149.6	5.505	170.0	6.333	184.7	7.172
90.2	3.445	109.0	4.020	130.4	4.802	150.6	5.531	170.5	6.354	184.2	7.191
90.9	3.458	109.0	4.025	130.6	4.816	151.0	5.554	170.5	6.367	184.0	7.208
91.2	3.470	109.7	4.042	130.9	4.827	151.3	5.574	170.1	6.378	184.3	7.236
91.7	3.484	110.2	4.053	131.4	4.848	151.1	5.586	170.5	6.396	184.5	7.258
91.9	3.499	110.8	4.069	132.0	4.870	152.5	5.610	171.7	6.422	184.5	7.281
92.4	3.510	111.3	4.087	132.8	4.886	153.0	5.636	172.3	6.441	184.3	7.305
93.1	3.524	111.7	4.107	133.2	4.906	153.9	5.660	172.7	6.460	184.6	7.330
93.1	3.535	112.3	4.117	133.2	4.923	154.0	5.674	173.0	6.479	184.2	7.349
93.0	3.542	112.2	4.125	133.1	4.937	154.2	5.689	172.8	6.492	184.0	7.368
94.0	3.558	113.0	4.154	134.1	4.951	154.0	5.700	173.2	6.507	184.3	7.398
94.6	3.572	113.5	4.204	135.1	4.977	155.2	5.728	174.2	6.529	183.7	7.433
94.8	3.589	114.5	4.222	135.9	4.999	155.7	5.746	174.5	6.550	182.8	7.461
95.3	3.605	115.0	4.240	136.3	5.021	156.2	5.766	175.3	6.573	180.5	7.509
96.0	3.618	115.3	4.257	136.5	5.034	156.4	5.785	175.5	6.590	29.7	9.413
96.1	3.629	115.4	4.267	136.5	5.042	156.8	5.805	175.6	6.603		
96.2	3.641	116.3	4.285	137.4	5.061	156.9	5.813	176.2	6.631		
96.2	3.649	117.1	4.303	137.8	5.081	157.6	5.834	176.9	6.658		
97.0	3.662	117.7	4.330	138.2	5.096	158.5	5.858	177.2	6.676		
97.6	3.677	118.4	4.363	138.5	5.113	159.3	5.884	177.4	6.695		
98.5	3.694	118.9	4.383	139.1	5.130	159.8	5.901	177.6	6.713		

Wallette 10

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
0.0	0.000	25.1	0.702	37.8	1.008	47.2	1.291	56.0	1.573	66.8	1.870
0.5	0.004	25.4	0.714	38.3	1.016	47.5	1.299	56.2	1.580	67.4	1.882
0.6	0.021	25.4	0.718	38.5	1.023	47.8	1.308	56.5	1.588	67.8	1.891
1.1	0.032	25.6	0.720	38.9	1.029	48.1	1.317	56.7	1.594	68.2	1.900
1.3	0.042	26.9	0.743	38.9	1.036	48.1	1.325	57.2	1.605	68.5	1.909
1.8	0.053	27.8	0.759	39.2	1.039	48.6	1.333	57.8	1.612	68.4	1.917
2.0	0.071	27.7	0.769	39.1	1.047	48.5	1.338	57.9	1.619	69.0	1.922
2.7	0.093	28.2	0.780	39.4	1.053	48.9	1.347	58.0	1.625	69.4	1.933
3.4	0.119	28.7	0.789	39.9	1.060	49.0	1.353	58.1	1.632	69.4	1.941
4.0	0.133	29.0	0.796	40.3	1.068	49.4	1.361	58.1	1.634	70.1	1.952
4.4	0.152	29.0	0.801	40.3	1.075	49.3	1.368	58.2	1.643	70.4	1.961
5.1	0.177	29.2	0.808	40.2	1.081	49.6	1.378	58.6	1.651	70.8	1.969
5.9	0.216	29.9	0.814	40.5	1.088	49.9	1.384	58.9	1.660	71.2	1.978
6.9	0.240	29.7	0.820	41.1	1.097	50.1	1.391	59.3	1.668	71.2	1.988
7.9	0.269	30.6	0.832	41.2	1.108	50.5	1.397	59.6	1.677	71.3	1.991
8.1	0.280	30.9	0.838	41.3	1.113	50.8	1.406	60.1	1.685	72.1	2.004
9.0	0.306	31.3	0.845	41.5	1.116	50.7	1.410	60.3	1.693	72.6	2.017
9.8	0.329	31.1	0.850	41.6	1.124	51.3	1.418	60.7	1.700	73.0	2.031
10.9	0.350	31.6	0.857	41.8	1.132	51.6	1.427	60.7	1.706	73.5	2.041
11.6	0.376	31.9	0.864	42.1	1.137	51.8	1.435	60.7	1.709	73.8	2.051
13.1	0.408	32.1	0.871	42.1	1.143	51.8	1.440	61.5	1.722	73.9	2.059
13.8	0.431	32.6	0.880	42.9	1.150	52.1	1.448	61.3	1.729	74.4	2.066
14.3	0.449	33.4	0.885	43.1	1.160	52.5	1.456	61.9	1.737	74.4	2.071
14.6	0.457	33.2	0.892	43.2	1.168	52.7	1.469	62.1	1.745	75.0	2.083
15.7	0.481	33.4	0.899	43.5	1.177	53.1	1.475	62.8	1.756	75.5	2.092
16.4	0.498	34.5	0.912	43.8	1.184	53.3	1.483	62.8	1.764	75.8	2.102
16.9	0.514	34.2	0.918	43.7	1.188	53.0	1.486	63.4	1.773	76.0	2.112
18.0	0.536	34.6	0.925	44.0	1.195	53.5	1.493	63.2	1.777	76.4	2.122
19.1	0.565	35.1	0.933	44.4	1.202	53.7	1.499	63.9	1.788	77.0	2.132
19.5	0.575	35.5	0.942	44.8	1.210	53.7	1.505	64.2	1.794	77.0	2.142
20.1	0.592	35.8	0.948	45.1	1.221	53.9	1.511	64.6	1.802	76.7	2.145
20.4	0.602	36.3	0.955	45.2	1.229	53.9	1.518	64.9	1.811	77.5	2.157
21.4	0.615	36.2	0.961	45.4	1.237	54.0	1.523	65.1	1.819	78.1	2.169
21.4	0.627	35.9	0.966	45.9	1.246	54.4	1.529	65.3	1.826	78.8	2.183
21.9	0.635	36.1	0.967	46.2	1.254	54.6	1.537	65.7	1.832	79.1	2.192
22.4	0.648	36.7	0.978	46.1	1.258	55.1	1.546	65.9	1.839	79.6	2.202
23.0	0.664	37.1	0.988	46.3	1.264	55.3	1.552	66.1	1.844	80.1	2.211
23.6	0.675	37.6	0.997	46.7	1.273	55.6	1.558	66.4	1.853	79.7	2.217
24.2	0.689	37.9	1.003	46.9	1.284	55.6	1.562	66.6	1.862	80.6	2.229

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
81.1	2.239	95.1	2.596	110.1	2.949	126.5	3.283	142.8	3.652	162.1	4.077
81.2	2.248	95.3	2.604	110.3	2.955	126.9	3.291	143.7	3.665	163.2	4.094
81.5	2.258	95.7	2.614	111.0	2.965	126.9	3.299	144.2	3.676	164.2	4.113
81.8	2.265	95.9	2.622	111.2	2.972	127.8	3.309	144.7	3.685	164.2	4.125
82.2	2.274	96.8	2.634	111.7	2.981	128.4	3.319	145.4	3.695	165.1	4.136
82.3	2.282	97.4	2.645	112.5	2.990	129.1	3.329	145.7	3.705	165.2	4.146
82.5	2.290	97.8	2.654	112.5	3.002	129.7	3.341	146.2	3.714	165.3	4.154
82.4	2.292	97.5	2.657	112.8	3.007	130.0	3.349	146.2	3.717	165.7	4.163
83.0	2.304	98.4	2.670	113.1	3.014	130.0	3.358	146.8	3.730	165.8	4.172
83.7	2.313	98.7	2.679	113.5	3.019	130.3	3.363	147.5	3.740	166.4	4.182
84.0	2.326	99.2	2.693	113.0	3.024	131.5	3.378	148.1	3.751	167.2	4.193
84.3	2.335	99.8	2.702	113.8	3.033	132.0	3.387	148.5	3.760	167.6	4.203
84.9	2.344	100.1	2.713	114.2	3.040	132.4	3.398	148.8	3.768	167.9	4.212
85.5	2.353	100.9	2.723	114.4	3.047	132.5	3.407	149.5	3.778	168.0	4.221
85.6	2.362	100.6	2.730	115.0	3.056	133.4	3.419	148.7	3.790	168.1	4.228
85.7	2.366	101.1	2.735	115.5	3.064	133.4	3.426	149.9	3.802	169.1	4.239
86.3	2.380	101.6	2.748	116.0	3.072	133.4	3.430	150.9	3.814	169.7	4.251
87.1	2.393	102.0	2.757	116.4	3.079	134.0	3.443	151.2	3.825	170.6	4.265
87.8	2.408	102.5	2.768	116.4	3.087	134.6	3.454	152.1	3.838	171.3	4.277
87.8	2.416	103.0	2.778	116.6	3.090	135.2	3.464	152.0	3.849	171.4	4.285
88.6	2.425	103.5	2.787	117.0	3.099	135.3	3.475	153.1	3.859	171.4	4.292
88.6	2.434	103.4	2.794	118.1	3.110	135.8	3.485	152.7	3.867	172.5	4.304
88.7	2.441	103.8	2.802	118.6	3.122	136.3	3.496	154.2	3.889	173.6	4.320
89.3	2.452	103.7	2.804	119.1	3.129	136.5	3.503	155.4	3.903	173.7	4.329
89.9	2.463	104.5	2.815	119.3	3.138	136.8	3.512	155.5	3.916	174.2	4.340
90.5	2.475	104.5	2.824	119.8	3.147	137.6	3.523	155.9	3.927	174.2	4.351
91.0	2.488	105.0	2.833	120.1	3.155	138.1	3.535	155.8	3.934	174.7	4.360
91.5	2.497	105.6	2.841	120.1	3.159	138.6	3.544	157.0	3.947	174.1	4.365
91.8	2.505	106.1	2.850	120.6	3.169	138.6	3.555	157.1	3.959	175.1	4.379
91.4	2.510	106.5	2.860	121.1	3.178	139.0	3.563	158.2	3.971	175.5	4.394
91.9	2.519	106.7	2.871	121.7	3.187	139.3	3.573	158.3	3.983	176.6	4.407
91.9	2.527	106.8	2.877	122.1	3.195	139.8	3.578	158.8	3.991	176.7	4.415
92.7	2.536	107.2	2.886	122.6	3.204	139.8	3.586	159.0	4.002	177.1	4.424
93.4	2.544	107.6	2.896	122.7	3.213	140.3	3.596	159.1	4.007	177.1	4.433
93.1	2.555	108.7	2.906	123.3	3.223	141.0	3.606	159.9	4.021	177.1	4.441
93.6	2.561	108.7	2.912	123.5	3.227	141.3	3.614	160.4	4.031	178.1	4.453
94.0	2.568	109.2	2.921	123.8	3.239	141.7	3.624	161.0	4.042	178.1	4.461
94.2	2.575	109.4	2.928	124.6	3.251	142.4	3.633	161.4	4.053	178.8	4.471
94.4	2.582	109.9	2.938	125.6	3.264	142.6	3.641	161.9	4.064	179.2	4.481
94.4	2.585	110.3	2.944	126.2	3.274	142.8	3.647	162.1	4.071	179.3	4.489

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
179.6	4.497	197.5	4.971								
179.8	4.505	198.2	4.986								
179.7	4.511	198.3	5.000								
180.9	4.524	198.4	5.013								
181.5	4.536	198.2	5.024								
182.2	4.547	199.2	5.043								
182.3	4.560	199.7	5.067								
182.7	4.567	200.3	5.082								
183.0	4.577	200.4	5.096								
183.1	4.585	199.8	5.110								
184.0	4.600	201.3	5.133								
184.6	4.609	201.5	5.149								
185.1	4.622	201.3	5.168								
186.0	4.633	201.4	5.185								
186.0	4.645	201.0	5.202								
186.4	4.651	201.2	5.223								
186.8	4.667	200.9	5.252								
187.5	4.680										
188.1	4.696										
188.5	4.704										
189.0	4.715										
188.8	4.724										
189.8	4.738										
190.2	4.749										
190.8	4.762										
191.4	4.775										
191.9	4.790										
191.6	4.797										
192.7	4.813										
192.8	4.827										
193.3	4.843										
193.7	4.854										
194.4	4.868										
194.3	4.877										
195.3	4.895										
195.2	4.907										
195.7	4.919										
196.2	4.931										
196.5	4.945										
196.3	4.952										

Experimental data from the masonry wallettes tested at 600ºC.

Wallette 11

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
0.0	0.000	15.6	0.725	26.9	1.140	31.7	1.385	36.3	1.627	40.9	1.890
0.2	0.017	16.4	0.745	27.5	1.149	31.7	1.390	36.3	1.633	41.3	1.896
0.7	0.056	16.6	0.758	27.6	1.159	31.7	1.395	36.4	1.639	41.6	1.903
1.2	0.089	17.6	0.774	27.7	1.167	32.0	1.402	36.5	1.644	41.4	1.911
1.6	0.105	17.3	0.789	27.4	1.175	32.0	1.404	36.5	1.650	41.5	1.918
2.2	0.134	17.7	0.800	27.6	1.181	32.0	1.413	36.8	1.658	41.9	1.926
2.7	0.164	18.9	0.816	27.7	1.188	32.4	1.420	36.8	1.666	41.9	1.933
3.1	0.189	19.5	0.831	28.0	1.194	32.4	1.429	37.0	1.671	42.1	1.940
3.6	0.217	19.5	0.843	27.8	1.200	32.6	1.434	37.2	1.679	42.0	1.946
4.5	0.242	20.0	0.855	28.0	1.204	32.6	1.441	37.3	1.687	42.3	1.954
4.8	0.265	20.5	0.869	27.8	1.209	33.0	1.450	37.5	1.698	42.2	1.960
5.1	0.279	20.7	0.880	28.1	1.213	33.3	1.460	37.7	1.704	42.6	1.968
5.5	0.308	21.2	0.891	28.2	1.219	33.5	1.466	37.9	1.713	42.6	1.972
5.8	0.335	21.4	0.907	28.3	1.223	33.6	1.472	38.1	1.721	42.8	1.984
6.2	0.360	21.9	0.922	28.5	1.229	33.9	1.479	38.1	1.726	43.1	1.991
6.7	0.376	21.7	0.927	28.5	1.233	33.1	1.482	38.2	1.730	43.5	2.000
7.1	0.395	22.3	0.948	29.2	1.252	33.5	1.489	38.4	1.741	43.7	2.009
7.6	0.418	22.6	0.963	29.7	1.260	33.8	1.496	38.6	1.749	43.5	2.018
7.9	0.439	23.0	0.976	29.7	1.267	34.1	1.502	38.9	1.761	43.7	2.024
8.5	0.460	23.5	0.985	29.7	1.275	34.0	1.508	38.9	1.766	44.1	2.031
8.7	0.478	23.7	0.995	30.1	1.284	34.0	1.513	39.1	1.775	44.1	2.037
9.4	0.498	24.0	1.004	30.0	1.288	34.4	1.520	39.3	1.781	44.3	2.047
9.6	0.510	24.1	1.010	29.9	1.292	34.4	1.526	39.3	1.788	44.4	2.053
9.9	0.524	24.2	1.019	30.1	1.297	34.6	1.537	39.0	1.792	44.2	2.057
10.3	0.536	24.4	1.026	30.3	1.303	34.8	1.543	39.3	1.797	44.3	2.065
10.8	0.549	24.4	1.034	30.4	1.308	34.9	1.549	39.7	1.804	44.5	2.074
11.3	0.571	24.7	1.040	30.4	1.315	35.1	1.557	39.4	1.811	45.2	2.080
12.1	0.588	25.1	1.059	30.4	1.318	35.1	1.562	39.9	1.816	44.8	2.087
12.5	0.608	25.6	1.071	31.0	1.332	35.0	1.568	39.9	1.825	45.2	2.096
12.5	0.624	25.7	1.083	31.0	1.338	35.0	1.575	39.9	1.833	45.4	2.105
13.2	0.649	26.0	1.090	31.1	1.344	35.5	1.581	40.3	1.841	45.3	2.112
13.8	0.662	26.1	1.100	31.1	1.350	35.5	1.588	40.5	1.848	45.7	2.118
13.9	0.669	26.2	1.107	31.2	1.357	35.8	1.594	40.6	1.856	45.6	2.125
14.8	0.687	26.6	1.115	31.3	1.362	35.5	1.600	40.7	1.863	45.9	2.131
14.8	0.699	26.6	1.121	31.4	1.369	35.8	1.607	41.0	1.871	45.8	2.135
14.9	0.704	26.8	1.128	31.6	1.374	35.9	1.614	41.0	1.877	45.7	2.142
14.9	0.713	26.8	1.134	31.6	1.380	35.8	1.620	41.0	1.884	46.2	2.152

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
46.3	2.161	54.4	2.516	71.7	3.175	87.5	3.806	97.7	4.330	104.9	4.760
46.6	2.169	54.5	2.526	71.7	3.185	87.3	3.816	97.9	4.341	105.4	4.768
46.7	2.177	54.5	2.536	72.2	3.200	87.9	3.834	97.8	4.349	105.1	4.778
47.0	2.185	54.7	2.543	72.0	3.209	87.6	3.838	97.3	4.355	105.2	4.785
47.2	2.194	54.9	2.549	73.0	3.231	88.4	3.861	98.4	4.374	105.1	4.792
47.4	2.201	55.1	2.561	73.3	3.245	89.7	3.881	98.6	4.383	105.4	4.801
47.0	2.208	55.8	2.572	74.0	3.263	89.7	3.896	98.8	4.394	106.0	4.814
47.6	2.215	55.7	2.581	74.0	3.279	89.3	3.904	98.7	4.405	105.9	4.820
47.5	2.223	56.3	2.591	74.7	3.296	89.6	3.915	99.5	4.421	106.4	4.832
48.0	2.231	56.3	2.602	74.7	3.303	89.4	3.923	100.0	4.432	106.7	4.840
47.9	2.239	56.5	2.612	75.0	3.318	89.4	3.931	101.0	4.450	106.7	4.852
48.3	2.246	57.4	2.630	75.1	3.328	89.6	3.938	100.8	4.461	107.5	4.867
48.0	2.254	57.0	2.635	74.7	3.337	89.2	3.947	100.9	4.472	107.9	4.881
48.6	2.261	58.6	2.666	75.8	3.355	89.4	3.954	101.2	4.481	108.0	4.893
48.6	2.269	59.5	2.690	76.3	3.372	90.1	3.972	101.2	4.491	107.8	4.902
48.8	2.276	60.3	2.707	76.9	3.391	90.8	3.992	101.1	4.500	109.3	4.917
49.2	2.283	61.2	2.731	77.2	3.408	91.3	4.005	101.5	4.511	109.4	4.929
49.2	2.291	61.8	2.753	77.5	3.417	91.7	4.016	101.6	4.519	109.6	4.941
49.2	2.296	61.8	2.769	77.6	3.426	91.9	4.030	101.8	4.530	110.0	4.952
49.4	2.315	61.7	2.781	77.4	3.436	91.7	4.036	101.6	4.539	110.0	4.961
50.4	2.329	61.7	2.789	77.5	3.447	91.9	4.046	101.8	4.548	110.5	4.973
50.4	2.338	61.7	2.795	78.0	3.457	92.1	4.057	101.7	4.553	110.4	4.981
50.7	2.347	62.6	2.820	78.9	3.477	92.9	4.076	101.9	4.563	110.5	4.995
50.7	2.355	63.1	2.840	79.3	3.498	92.8	4.085	101.9	4.573	110.9	5.003
50.9	2.366	64.3	2.866	81.1	3.524	93.4	4.101	102.5	4.587	111.0	5.013
50.9	2.373	65.3	2.888	81.3	3.541	94.1	4.117	102.9	4.598	111.8	5.027
51.6	2.382	65.4	2.907	81.6	3.558	93.8	4.137	102.8	4.607	112.4	5.044
51.1	2.388	65.9	2.923	81.8	3.576	93.5	4.144	103.0	4.615	112.4	5.052
51.8	2.398	65.9	2.940	81.6	3.584	93.2	4.152	103.4	4.625	112.4	5.064
51.8	2.405	65.6	2.947	82.7	3.603	93.1	4.160	103.4	4.632	113.3	5.077
52.0	2.413	67.6	2.984	83.2	3.622	93.5	4.171	103.4	4.638	113.2	5.091
51.8	2.422	68.0	3.002	84.5	3.649	93.3	4.180	103.5	4.648	113.4	5.101
52.4	2.431	68.7	3.022	84.7	3.666	94.5	4.198	103.6	4.660	113.8	5.112
52.4	2.437	68.8	3.039	84.4	3.674	95.0	4.214	104.0	4.671	114.0	5.125
52.5	2.444	68.9	3.054	84.7	3.687	95.5	4.229	104.0	4.680	114.0	5.134
52.5	2.451	68.9	3.063	84.6	3.700	95.7	4.240	103.7	4.690	114.4	5.145
52.4	2.460	69.0	3.077	84.7	3.711	96.3	4.257	103.7	4.700	114.8	5.159
52.5	2.464	69.0	3.089	85.8	3.732	96.8	4.273	103.8	4.708	115.2	5.174
53.4	2.480	70.5	3.114	85.8	3.744	97.1	4.288	103.8	4.717	115.4	5.187
53.7	2.491	70.9	3.130	86.3	3.761	96.9	4.295	104.2	4.727	116.0	5.197
53.7	2.501	71.4	3.146	87.2	3.786	96.9	4.303	104.9	4.741	116.1	5.208
54.4	2.508	71.8	3.163	87.3	3.795	97.0	4.313	105.1	4.750	116.1	5.217

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
116.8	5.234	133.0	5.900	155.2	6.808	173.9	8.115				
117.2	5.245	133.7	5.914	154.5	6.824	172.8	8.137				
117.7	5.262	133.9	5.932	156.0	6.861	174.9	8.188				
118.4	5.279	133.5	5.941	156.9	6.895	174.3	8.222				
118.2	5.291	134.1	5.962	156.4	6.921	175.9	8.282				
119.0	5.307	135.4	5.985	156.9	6.946	175.0	8.311				
120.0	5.324	135.9	6.002	157.6	6.977	176.0	8.358				
120.5	5.345	135.5	6.014	157.5	6.997	176.0	8.400				
121.1	5.364	136.4	6.038	158.4	7.034	177.5	8.462				
120.8	5.374	136.8	6.053	159.3	7.062	176.5	8.491				
121.5	5.392	137.5	6.074	158.5	7.086	176.3	8.532				
122.0	5.407	137.7	6.089	160.6	7.128	177.4	8.579				
122.7	5.426	138.5	6.114	160.7	7.160	176.9	8.626				
123.0	5.440	139.1	6.135	161.3	7.187	177.0	8.662				
122.7	5.449	140.0	6.159	162.1	7.220	175.0	8.692				
123.6	5.469	139.1	6.171	161.7	7.246	176.5	8.741				
124.5	5.490	140.4	6.196	161.8	7.275	175.4	8.785				
124.8	5.504	141.1	6.216	162.1	7.301	175.8	8.823				
125.3	5.523	141.7	6.239	163.1	7.335	176.6	8.872				
125.5	5.535	141.1	6.253	162.8	7.359	175.3	8.905				
126.6	5.559	142.5	6.282	164.8	7.409	176.7	8.966				
127.6	5.578	143.4	6.304	164.1	7.426	175.5	8.996				
128.0	5.599	143.7	6.324	164.7	7.457	177.1	9.059				
127.6	5.610	143.8	6.344	166.4	7.500	175.5	9.096				
128.4	5.634	145.6	6.377	165.3	7.528	176.7	9.162				
129.0	5.651	146.0	6.398	166.4	7.558	175.3	9.193				
129.8	5.674	145.8	6.415	167.3	7.595	176.8	9.263				
129.4	5.686	146.8	6.441	167.0	7.622	177.6	9.332				
130.6	5.711	148.2	6.477	168.9	7.676	176.8	9.401				
131.0	5.727	147.6	6.490	168.1	7.696	176.0	9.461				
131.8	5.748	148.5	6.519	168.4	7.731	174.6	9.519				
131.6	5.761	150.2	6.554	169.4	7.768	173.1	9.584				
131.6	5.786	149.6	6.578	169.2	7.802	170.5	9.649				
131.6	5.796	150.8	6.602	170.7	7.838	169.0	9.698				
132.3	5.814	151.8	6.637	170.2	7.866	165.7	9.741				
132.5	5.830	151.5	6.658	171.5	7.911	164.2	9.800				
132.3	5.845	152.8	6.694	171.6	7.952	160.4	9.867				
132.2	5.852	153.5	6.722	171.6	7.979	157.3	9.924				
132.2	5.866	153.1	6.740	173.4	8.031	0.8	15.504				
132.4	5.881	153.9	6.771	172.7	8.058	0.9	15.472				

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Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
0.0	0.000	17.5	0.784	29.6	1.208	38.1	1.575	45.7	1.961	53.8	2.393
0.3	0.031	17.7	0.798	29.7	1.217	37.8	1.582	46.0	1.971	54.2	2.406
0.5	0.045	18.1	0.808	30.2	1.227	37.9	1.587	46.1	1.984	54.6	2.417
1.0	0.060	18.5	0.827	30.0	1.234	38.9	1.609	46.6	1.992	54.2	2.425
1.1	0.077	19.0	0.839	30.4	1.243	38.7	1.620	46.4	2.001	54.6	2.436
1.8	0.105	19.3	0.849	31.1	1.260	38.8	1.627	46.5	2.011	54.7	2.446
2.5	0.138	19.8	0.863	31.2	1.271	38.9	1.636	47.0	2.025	55.1	2.456
2.8	0.146	19.9	0.876	31.4	1.277	39.1	1.646	47.2	2.034	55.6	2.466
2.7	0.165	21.0	0.893	31.4	1.286	39.1	1.656	47.5	2.045	55.6	2.476
3.7	0.193	21.0	0.904	31.4	1.294	39.3	1.663	48.0	2.055	55.7	2.485
4.1	0.232	21.4	0.917	31.7	1.303	39.4	1.672	48.1	2.066	55.9	2.495
4.7	0.262	21.8	0.927	31.6	1.309	39.6	1.678	48.1	2.074	56.2	2.504
5.7	0.297	21.5	0.934	32.1	1.319	40.3	1.701	48.3	2.081	55.6	2.511
5.9	0.314	22.2	0.953	32.1	1.327	40.7	1.710	47.5	2.107	56.2	2.521
6.8	0.344	22.9	0.971	32.9	1.345	41.1	1.723	47.9	2.116	56.4	2.531
7.2	0.368	23.8	0.993	32.9	1.353	41.2	1.736	47.7	2.123	56.7	2.542
7.6	0.393	24.7	1.019	33.4	1.362	41.5	1.747	48.0	2.132	57.2	2.552
8.5	0.419	25.0	1.030	33.4	1.370	41.6	1.756	48.1	2.143	57.2	2.560
9.0	0.451	25.2	1.040	33.4	1.379	41.3	1.763	48.5	2.156	57.5	2.570
9.5	0.465	25.3	1.053	33.8	1.386	41.3	1.768	48.7	2.165	57.5	2.579
9.4	0.480	25.6	1.061	33.9	1.396	41.9	1.782	49.1	2.172	57.2	2.586
9.9	0.498	26.0	1.072	33.8	1.404	42.1	1.790	49.3	2.182	57.9	2.596
10.4	0.522	26.3	1.083	34.0	1.411	42.3	1.800	49.8	2.198	58.1	2.608
10.8	0.538	26.6	1.091	34.1	1.420	42.5	1.810	50.1	2.207	58.2	2.619
11.2	0.558	26.4	1.098	35.1	1.437	42.5	1.820	50.3	2.220	58.9	2.629
11.8	0.575	26.7	1.103	35.1	1.449	42.6	1.826	50.7	2.231	58.6	2.637
12.7	0.597	27.1	1.109	35.2	1.459	43.0	1.835	50.7	2.241	59.0	2.648
12.8	0.614	27.0	1.116	35.6	1.468	42.7	1.843	50.8	2.248	59.3	2.657
13.4	0.631	27.2	1.123	35.9	1.482	43.3	1.857	51.3	2.261	59.3	2.666
14.3	0.656	27.2	1.129	36.2	1.494	43.7	1.867	51.6	2.275	60.0	2.679
14.0	0.668	27.3	1.135	36.6	1.505	43.6	1.879	52.2	2.288	60.3	2.692
14.6	0.682	27.5	1.142	36.4	1.513	44.1	1.890	52.4	2.298	60.6	2.703
15.0	0.694	27.3	1.145	36.8	1.524	44.5	1.903	52.5	2.324	60.9	2.717
15.2	0.705	27.9	1.157	36.8	1.532	44.2	1.911	52.5	2.338	61.4	2.727
15.6	0.720	28.5	1.167	37.1	1.541	44.6	1.920	52.7	2.347	61.1	2.733
16.1	0.733	28.7	1.175	37.2	1.548	44.7	1.925	52.9	2.356	61.9	2.745
16.7	0.749	28.9	1.189	37.3	1.557	45.4	1.941	53.3	2.368	62.1	2.760
17.0	0.767	29.5	1.200	37.8	1.566	45.7	1.951	53.3	2.379	62.2	2.769

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
62.8	2.782	73.1	3.254	84.7	3.791	97.7	4.349	108.1	4.876	118.6	5.404
63.0	2.794	73.1	3.270	84.7	3.799	97.6	4.365	108.0	4.884	118.7	5.417
63.3	2.808	73.8	3.284	85.2	3.813	97.8	4.375	108.7	4.904	118.9	5.430
62.9	2.812	74.0	3.298	85.7	3.829	98.1	4.386	109.1	4.917	119.5	5.445
63.8	2.828	73.9	3.309	85.8	3.846	98.4	4.405	109.5	4.932	119.7	5.456
64.2	2.841	74.4	3.321	86.6	3.857	99.0	4.424	110.0	4.945	119.8	5.468
64.6	2.856	74.9	3.337	87.0	3.875	99.5	4.437	109.9	4.961	119.8	5.478
65.0	2.867	75.5	3.354	86.9	3.884	99.6	4.451	110.1	4.969	120.1	5.495
65.0	2.877	76.0	3.365	87.3	3.905	100.0	4.461	110.9	4.987	120.8	5.507
65.2	2.885	76.2	3.380	87.8	3.919	99.7	4.476	111.3	5.003	121.2	5.524
65.0	2.896	75.9	3.388	88.6	3.935	100.4	4.490	112.1	5.022	121.6	5.538
65.8	2.906	76.9	3.407	88.7	3.951	100.9	4.507	111.8	5.033	121.9	5.553
66.0	2.919	77.3	3.420	88.7	3.962	101.5	4.523	112.2	5.044	121.8	5.564
66.1	2.932	77.6	3.434	89.4	3.978	101.7	4.540	112.1	5.055	122.6	5.581
66.7	2.946	77.8	3.448	89.7	3.996	101.5	4.547	112.5	5.074	123.2	5.598
66.7	2.953	77.7	3.463	90.3	4.012	102.2	4.565	113.0	5.087	123.7	5.619
66.5	2.962	77.8	3.470	90.3	4.027	102.5	4.580	113.5	5.100	124.1	5.631
66.7	2.970	78.7	3.491	90.8	4.041	103.0	4.595	113.4	5.111	123.9	5.643
67.0	2.982	79.1	3.506	90.9	4.050	103.0	4.608	113.3	5.125	125.1	5.664
67.2	2.992	79.6	3.523	91.4	4.067	103.2	4.620	113.4	5.133	125.3	5.684
67.5	3.003	79.8	3.533	91.9	4.087	103.0	4.629	113.6	5.147	125.8	5.698
67.8	3.014	79.9	3.544	92.3	4.100	103.5	4.644	114.3	5.163	126.1	5.715
68.1	3.028	79.7	3.553	92.3	4.114	103.7	4.655	114.7	5.180	126.1	5.728
68.5	3.037	80.6	3.572	92.4	4.126	104.3	4.670	115.0	5.192	127.0	5.747
68.3	3.044	80.8	3.585	92.9	4.140	104.2	4.683	115.2	5.204	127.3	5.762
68.6	3.058	81.2	3.598	93.3	4.153	104.7	4.698	115.3	5.214	127.8	5.779
69.3	3.074	81.4	3.610	94.0	4.170	105.0	4.708	116.0	5.236	127.9	5.796
69.8	3.087	81.5	3.623	94.1	4.184	104.8	4.718	116.5	5.251	127.9	5.812
69.8	3.099	81.1	3.634	94.2	4.199	105.6	4.737	117.0	5.266	128.9	5.831
70.1	3.110	81.3	3.646	94.4	4.210	106.3	4.755	117.3	5.281	129.3	5.849
70.1	3.127	82.1	3.666	94.1	4.219	106.1	4.765	117.3	5.294	129.5	5.867
70.3	3.143	82.7	3.684	95.1	4.235	106.5	4.780	117.3	5.302	129.6	5.882
70.8	3.164	82.7	3.697	95.4	4.252	106.7	4.791	117.8	5.321	129.7	5.895
71.4	3.179	82.9	3.710	95.4	4.263	106.6	4.802	118.1	5.334	130.6	5.914
71.6	3.193	82.9	3.717	95.9	4.278	106.9	4.813	118.5	5.350	131.1	5.934
71.8	3.204	83.6	3.736	95.8	4.291	107.1	4.827	118.4	5.360	131.8	5.957
72.2	3.216	84.1	3.749	95.9	4.301	107.5	4.841	118.4	5.372	131.2	5.967
72.0	3.223	84.1	3.764	96.7	4.317	107.6	4.853	118.4	5.382	132.5	5.991
72.7	3.242	84.7	3.776	97.2	4.334	107.8	4.864	117.9	5.392	133.1	6.013

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
133.4	6.035	149.8	6.909	163.1	8.044						
133.2	6.047	150.3	6.934	163.4	8.076						
133.3	6.063	150.4	6.957	163.7	8.113						
134.0	6.086	149.9	6.978	163.3	8.136						
134.7	6.108	150.4	6.998	162.4	8.159						
134.9	6.124	151.0	7.025	164.2	8.201						
134.5	6.137	151.7	7.050	163.7	8.232						
135.1	6.157	150.9	7.070	163.5	8.258						
136.1	6.184	151.9	7.092	164.0	8.296						
136.7	6.202	152.6	7.120	164.0	8.326						
136.4	6.218	153.0	7.146	164.1	8.364						
136.9	6.234	152.7	7.170	164.6	8.397						
137.6	6.262	153.5	7.193	163.8	8.424						
137.9	6.280	154.1	7.222	164.7	8.465						
138.2	6.300	153.8	7.240	164.8	8.509						
138.4	6.316	154.1	7.267	163.5	8.530						
139.2	6.342	154.5	7.291	164.4	8.570						
139.6	6.362	154.8	7.317	164.6	8.608						
140.0	6.382	154.7	7.333	164.0	8.646						
139.8	6.398	155.7	7.369	164.3	8.681						
140.7	6.425	156.7	7.395	163.7	8.716						
141.5	6.445	156.2	7.416	163.4	8.748						
141.8	6.467	157.4	7.452	162.6	8.789						
141.8	6.484	158.3	7.490	162.4	8.815						
142.7	6.514	157.5	7.506	160.8	8.840						
143.2	6.535	158.8	7.540	160.7	8.875						
143.2	6.553	159.1	7.569	161.3	8.921						
144.1	6.580	158.2	7.592	159.8	8.941						
145.1	6.614	159.1	7.623	160.3	8.982						
145.5	6.633	160.2	7.659	159.8	9.020						
145.0	6.649	159.6	7.682	157.7	9.054						
146.0	6.678	161.4	7.729	157.7	9.090						
146.6	6.705	161.9	7.758	157.4	9.134						
146.4	6.721	161.9	7.786	155.4	9.166						
147.2	6.748	162.9	7.826	154.9	9.233						
147.4	6.774	162.0	7.855	150.5	9.290						
148.0	6.799	162.6	7.887								
147.1	6.810	163.3	7.922								
148.6	6.840	162.5	7.949								
149.7	6.867	163.4	7.991								
148.9	6.887	163.8	8.020								

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Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
0.0	0.000	22.0	0.917	34.2	1.346	40.6	1.670	47.2	1.970	53.9	2.291
0.3	0.008	22.5	0.931	34.3	1.356	40.3	1.674	47.0	1.977	53.8	2.300
0.4	0.005	22.8	0.942	35.3	1.373	40.9	1.687	47.4	1.986	54.3	2.308
0.5	0.004	23.4	0.961	35.3	1.385	41.3	1.697	47.3	1.992	54.2	2.314
0.8	0.028	23.8	0.978	36.2	1.400	41.2	1.703	47.5	1.999	54.5	2.323
1.0	0.056	24.7	0.996	36.2	1.410	41.5	1.710	47.6	2.009	55.0	2.335
1.1	0.082	24.9	1.006	36.0	1.416	41.7	1.717	47.8	2.017	55.2	2.342
1.6	0.097	25.1	1.018	36.5	1.433	41.8	1.725	48.0	2.025	55.1	2.352
2.1	0.132	25.7	1.032	36.8	1.445	41.9	1.730	48.1	2.033	55.5	2.361
2.4	0.158	26.1	1.046	37.1	1.453	42.1	1.737	48.4	2.040	55.7	2.371
3.1	0.193	26.1	1.051	37.0	1.462	42.0	1.744	48.8	2.050	55.5	2.378
3.3	0.203	26.4	1.060	37.2	1.470	42.2	1.752	48.8	2.058	56.0	2.385
3.7	0.228	26.9	1.076	37.3	1.477	42.2	1.755	49.1	2.067	56.0	2.394
4.4	0.250	27.3	1.090	37.3	1.485	42.5	1.763	49.1	2.073	56.1	2.403
5.1	0.283	27.3	1.100	37.5	1.494	42.4	1.770	49.2	2.079	56.5	2.412
5.4	0.312	27.7	1.106	37.5	1.501	42.7	1.778	49.5	2.089	56.9	2.422
6.2	0.340	28.0	1.116	37.6	1.506	42.7	1.784	49.7	2.100	57.4	2.431
6.5	0.357	28.6	1.132	37.9	1.517	42.8	1.790	49.7	2.106	57.3	2.442
7.4	0.392	29.0	1.144	38.5	1.529	43.3	1.798	50.1	2.114	57.7	2.450
8.2	0.416	29.1	1.153	38.3	1.535	43.4	1.807	50.3	2.124	57.6	2.460
9.0	0.452	29.4	1.160	38.4	1.543	43.6	1.814	50.4	2.134	57.8	2.468
9.5	0.473	29.8	1.169	38.8	1.551	43.4	1.822	50.7	2.141	57.7	2.474
10.2	0.509	30.1	1.180	38.9	1.560	42.7	1.828	50.7	2.149	58.2	2.484
10.5	0.523	30.3	1.190	38.9	1.567	43.7	1.834	50.8	2.156	58.7	2.499
11.5	0.567	30.6	1.202	39.1	1.573	43.7	1.839	51.0	2.165	58.7	2.508
12.6	0.591	30.8	1.213	39.2	1.580	44.3	1.848	51.2	2.173	58.9	2.518
13.1	0.612	30.9	1.217	39.5	1.588	44.2	1.854	51.8	2.183	58.7	2.526
13.8	0.635	31.4	1.229	39.1	1.591	44.4	1.864	51.6	2.192	59.4	2.537
14.5	0.669	32.1	1.246	39.5	1.599	44.6	1.870	51.7	2.201	59.5	2.546
15.4	0.691	32.2	1.256	39.5	1.605	44.8	1.878	52.1	2.208	59.6	2.555
15.7	0.711	32.3	1.262	39.6	1.613	44.9	1.887	52.4	2.218	60.0	2.568
18.4	0.738	32.3	1.269	39.4	1.618	45.2	1.897	52.5	2.225	60.5	2.580
17.4	0.766	33.0	1.277	39.6	1.624	45.6	1.903	52.7	2.234	60.8	2.592
18.3	0.790	32.3	1.285	39.8	1.630	45.4	1.910	52.4	2.238	61.2	2.604
18.7	0.814	32.7	1.290	40.1	1.638	45.2	1.917	52.9	2.248	61.3	2.613
19.8	0.840	32.9	1.298	40.0	1.644	46.3	1.935	53.1	2.257	61.3	2.621
20.6	0.866	33.1	1.309	40.3	1.650	46.3	1.944	53.0	2.266	61.4	2.630
20.6	0.877	33.9	1.323	40.2	1.657	46.7	1.952	53.8	2.274	61.4	2.638
21.7	0.899	34.0	1.337	40.5	1.665	46.9	1.960	53.6	2.283	62.0	2.648

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
62.3	2.661	70.6	3.043	79.9	3.449	88.0	3.881	98.4	4.324	106.8	4.731
62.5	2.671	70.9	3.057	80.3	3.462	88.1	3.892	98.3	4.334	107.1	4.740
63.0	2.682	71.4	3.069	80.6	3.474	88.8	3.905	98.5	4.345	106.9	4.747
62.9	2.691	71.6	3.079	80.6	3.483	88.7	3.914	98.5	4.354	107.2	4.759
63.0	2.700	72.2	3.089	80.9	3.493	89.1	3.924	98.9	4.364	107.7	4.769
63.5	2.709	72.1	3.099	81.0	3.504	89.4	3.934	99.1	4.377	107.7	4.780
63.2	2.718	72.3	3.110	81.3	3.516	89.3	3.944	99.6	4.391	108.0	4.793
63.3	2.725	72.5	3.117	81.8	3.523	89.8	3.955	99.8	4.401	108.3	4.803
63.6	2.736	72.6	3.125	81.6	3.532	90.1	3.967	100.1	4.412	108.6	4.813
64.3	2.746	73.0	3.137	82.0	3.544	90.7	3.978	100.3	4.423	108.9	4.823
64.2	2.758	73.2	3.151	82.5	3.557	90.8	3.989	100.6	4.433	109.1	4.834
64.7	2.768	73.6	3.159	82.5	3.566	90.7	3.997	100.3	4.437	109.8	4.846
65.0	2.777	73.4	3.170	82.8	3.576	91.1	4.007	100.9	4.452	109.9	4.859
65.1	2.787	74.0	3.180	82.9	3.588	91.3	4.015	101.2	4.463	110.1	4.870
65.4	2.798	73.8	3.189	83.0	3.599	91.2	4.023	101.7	4.476	109.8	4.884
65.2	2.802	74.0	3.197	83.1	3.607	91.4	4.033	101.9	4.484	110.7	4.894
65.5	2.814	74.4	3.203	83.4	3.616	92.0	4.044	102.2	4.493	110.9	4.903
66.1	2.824	74.7	3.215	83.9	3.627	92.3	4.057	102.1	4.503	110.6	4.910
66.2	2.836	74.9	3.228	84.2	3.640	92.6	4.070	102.0	4.512	111.3	4.925
66.4	2.845	75.2	3.236	84.3	3.649	92.5	4.077	102.1	4.520	111.5	4.935
66.6	2.855	75.4	3.247	84.8	3.660	92.9	4.086	102.5	4.531	111.7	4.948
66.7	2.865	75.7	3.259	84.5	3.670	93.0	4.095	102.9	4.542	112.0	4.960
66.9	2.875	75.8	3.270	83.2	3.703	92.9	4.105	102.9	4.553	112.3	4.971
66.9	2.881	76.0	3.277	83.2	3.705	93.7	4.116	103.5	4.561	112.3	4.986
67.4	2.895	76.1	3.287	83.2	3.712	93.8	4.127	103.9	4.571	112.5	5.002
68.0	2.906	76.6	3.298	83.5	3.722	94.2	4.137	103.5	4.582	112.8	5.018
67.9	2.917	76.9	3.312	83.7	3.733	94.1	4.160	103.5	4.591	113.2	5.035
68.4	2.925	77.0	3.319	84.0	3.741	94.8	4.177	104.2	4.601	113.4	5.047
68.4	2.934	77.2	3.330	84.4	3.751	95.0	4.187	104.4	4.612	114.0	5.062
68.4	2.943	77.3	3.339	85.1	3.762	94.8	4.195	104.6	4.623	114.2	5.073
68.4	2.953	77.5	3.350	85.1	3.774	95.4	4.211	105.1	4.638	114.3	5.085
68.7	2.959	77.7	3.358	85.3	3.782	96.0	4.222	105.7	4.646	114.4	5.092
69.0	2.971	78.0	3.365	85.7	3.792	96.6	4.238	105.5	4.656	115.0	5.109
69.4	2.983	78.5	3.378	86.2	3.805	96.7	4.252	105.5	4.665	115.7	5.125
69.7	2.994	78.5	3.389	86.4	3.817	96.9	4.264	105.8	4.674	115.9	5.146
69.8	3.003	79.0	3.399	86.9	3.828	96.8	4.271	105.8	4.682	116.5	5.161
70.1	3.012	79.1	3.410	87.3	3.841	96.8	4.277	106.1	4.692	116.4	5.174
70.2	3.020	79.3	3.420	87.5	3.853	97.4	4.292	106.3	4.702	116.5	5.183
70.4	3.030	79.5	3.432	87.3	3.861	97.7	4.304	106.3	4.714	117.0	5.202
70.3	3.036	79.6	3.440	87.8	3.871	97.6	4.313	106.7	4.722	117.2	5.214

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
117.7	5.230	129.3	5.802	142.4	6.625	157.5	7.634	155.3	9.139		
117.8	5.243	130.0	5.824	143.0	6.645	157.5	7.660	155.2	9.191		
118.2	5.258	130.2	5.842	143.3	6.668	158.2	7.696	152.1	9.235		
118.0	5.266	130.8	5.859	142.6	6.684	158.2	7.729	151.7	9.282		
118.4	5.281	130.9	5.873	143.6	6.712	158.5	7.754	149.0	9.348		
118.9	5.295	131.7	5.899	144.6	6.735	159.9	7.798	143.4	9.413		
119.2	5.311	132.1	5.917	144.9	6.758	158.6	7.821				
119.3	5.323	132.9	5.938	144.6	6.777	160.4	7.874				
119.6	5.336	132.4	5.952	145.0	6.803	160.7	7.903				
120.0	5.347	132.9	5.978	145.6	6.825	160.3	7.931				
119.6	5.360	133.5	5.993	145.8	6.846	161.4	7.973				
120.3	5.373	133.8	6.013	145.6	6.862	160.3	8.005				
120.4	5.388	134.1	6.029	146.3	6.891	161.5	8.042				
120.7	5.400	133.4	6.044	147.2	6.914	162.1	8.082				
120.9	5.413	134.0	6.061	147.3	6.937	160.8	8.111				
120.9	5.423	134.5	6.080	147.3	6.958	162.2	8.159				
121.0	5.434	135.1	6.101	148.1	6.987	161.8	8.185				
120.9	5.442	135.9	6.123	148.6	7.009	161.8	8.219				
121.4	5.458	135.5	6.135	148.2	7.026	162.5	8.260				
121.5	5.468	135.2	6.171	148.3	7.049	161.1	8.293				
121.7	5.481	135.3	6.194	148.9	7.076	162.2	8.328				
122.4	5.495	135.5	6.218	149.4	7.097	162.2	8.368				
122.2	5.509	135.8	6.232	149.3	7.117	160.9	8.394				
122.6	5.520	135.4	6.249	150.0	7.142	162.4	8.452				
122.0	5.529	135.9	6.267	150.8	7.173	162.1	8.480				
123.2	5.545	136.0	6.289	151.2	7.195	161.7	8.514				
123.4	5.561	136.5	6.308	150.4	7.213	162.4	8.557				
124.1	5.576	136.4	6.324	151.3	7.240	162.1	8.599				
124.9	5.594	136.8	6.343	152.5	7.273	162.5	8.640				
124.9	5.607	137.2	6.368	152.2	7.289	162.3	8.675				
125.2	5.625	138.3	6.389	152.7	7.315	160.5	8.705				
125.7	5.638	138.7	6.410	153.2	7.346	161.2	8.751				
126.1	5.656	138.3	6.426	153.6	7.377	160.8	8.783				
126.8	5.674	139.2	6.453	153.7	7.399	160.1	8.815				
127.0	5.690	139.9	6.473	154.9	7.429	161.4	8.865				
127.0	5.701	140.3	6.495	155.0	7.459	159.8	8.902				
127.8	5.720	139.9	6.511	154.4	7.481	159.9	8.943				
127.8	5.736	140.7	6.537	154.9	7.505	159.3	8.986				
128.2	5.756	141.3	6.557	156.2	7.542	157.7	9.019				
128.7	5.770	141.8	6.580	155.8	7.564	157.5	9.069				
128.5	5.782	141.7	6.597	157.7	7.610	156.8	9.103				

Experimental data from the masonry wallettes tested at 700ºC.

Wallette 17

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
0.0	0.000	7.7	0.965	18.8	2.095	25.6	2.910	30.8	3.515	35.1	4.080
0.4	0.005	8.1	1.000	19.1	2.125	25.6	2.930	30.8	3.530	35.3	4.095
0.6	0.015	8.3	1.025	19.6	2.155	25.9	2.945	31.2	3.545	35.6	4.115
0.8	0.035	8.4	1.040	19.5	2.175	25.7	2.960	31.0	3.555	35.7	4.125
1.1	0.085	9.1	1.075	20.0	2.205	25.7	2.970	31.4	3.575	35.8	4.145
1.2	0.115	10.1	1.120	19.8	2.225	26.3	2.990	31.0	3.585	35.6	4.155
1.2	0.125	10.2	1.145	20.3	2.255	25.8	3.000	31.2	3.605	35.7	4.160
1.1	0.150	10.4	1.185	20.0	2.260	26.2	3.020	31.4	3.615	35.6	4.165
1.3	0.190	10.9	1.210	20.5	2.300	26.5	3.035	31.7	3.625	35.6	4.175
1.4	0.220	11.2	1.230	20.9	2.320	26.9	3.060	32.0	3.645	36.0	4.200
1.8	0.240	11.7	1.260	20.8	2.345	26.8	3.075	31.9	3.665	36.0	4.210
1.8	0.260	11.6	1.290	21.2	2.370	27.6	3.105	32.6	3.685	36.3	4.230
2.0	0.300	12.1	1.320	21.2	2.400	27.6	3.125	32.6	3.715	36.6	4.240
1.9	0.325	12.6	1.365	21.6	2.420	27.5	3.140	33.2	3.735	36.7	4.260
2.2	0.345	13.3	1.395	21.7	2.450	28.0	3.150	33.2	3.755	36.6	4.270
2.5	0.370	13.2	1.425	21.7	2.460	27.4	3.165	33.3	3.765	36.6	4.280
2.2	0.410	13.6	1.455	21.9	2.490	27.8	3.175	33.0	3.775	36.9	4.290
2.5	0.425	14.3	1.515	22.6	2.515	27.9	3.195	33.4	3.800	36.3	4.295
2.8	0.455	14.7	1.545	23.0	2.560	28.0	3.210	33.6	3.825	36.9	4.310
3.1	0.480	15.0	1.605	23.3	2.590	28.2	3.230	34.1	3.840	36.8	4.320
3.0	0.515	15.2	1.630	23.4	2.620	28.5	3.245	34.3	3.865	36.9	4.330
3.2	0.525	15.0	1.660	23.6	2.640	28.7	3.265	34.3	3.880	36.9	4.340
3.6	0.560	16.1	1.690	23.5	2.665	28.9	3.280	33.9	3.895	36.8	4.350
3.8	0.585	16.0	1.725	23.4	2.670	28.8	3.295	34.1	3.900	37.0	4.360
4.2	0.620	16.3	1.750	23.9	2.695	28.7	3.310	33.8	3.910	37.1	4.370
4.2	0.625	16.7	1.790	23.7	2.715	28.9	3.320	33.9	3.920	37.2	4.380
4.8	0.655	16.7	1.820	23.8	2.735	28.7	3.325	34.4	3.940	36.8	4.385
4.4	0.675	17.1	1.840	24.0	2.750	29.4	3.350	34.6	3.960	36.9	4.395
5.0	0.705	16.9	1.850	24.4	2.775	29.4	3.370	34.9	3.980	37.2	4.405
5.3	0.735	16.9	1.880	24.6	2.790	30.1	3.395	34.8	3.990	37.3	4.425
5.5	0.755	17.1	1.900	24.6	2.810	30.3	3.415	34.9	4.005	37.8	4.435
5.4	0.780	17.8	1.930	24.8	2.820	29.9	3.435	34.8	4.015	38.1	4.455
6.4	0.820	17.6	1.955	24.7	2.835	30.0	3.445	34.3	4.025	38.5	4.475
6.2	0.845	17.9	1.990	24.4	2.845	29.9	3.455	34.7	4.035	38.5	4.490
6.8	0.880	18.4	2.010	24.3	2.865	29.8	3.465	34.4	4.045	38.8	4.495
7.0	0.900	18.6	2.045	24.6	2.875	30.1	3.475	34.6	4.050	38.5	4.505
7.5	0.940	18.5	2.055	25.2	2.895	30.4	3.495	34.8	4.065	38.0	4.515

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
38.5	4.525	42.0	5.005	48.1	5.570	53.1	6.170	60.8	6.890	63.4	7.525
39.0	4.545	42.6	5.020	48.0	5.585	54.1	6.195	60.5	6.900	63.6	7.540
39.0	4.560	42.7	5.035	48.0	5.605	54.2	6.210	60.7	6.930	63.5	7.550
39.5	4.570	43.1	5.055	48.6	5.615	54.6	6.230	61.1	6.945	63.5	7.565
39.5	4.590	43.4	5.065	48.4	5.630	54.4	6.245	61.1	6.965	63.6	7.570
39.6	4.600	43.2	5.080	48.5	5.645	54.6	6.260	61.7	6.985	63.5	7.590
39.3	4.610	43.1	5.085	48.8	5.660	54.1	6.270	61.5	7.005	63.7	7.600
39.4	4.620	43.2	5.105	48.7	5.675	54.1	6.280	61.3	7.015	63.7	7.610
39.2	4.630	43.6	5.120	48.8	5.685	53.9	6.290	60.9	7.025	63.1	7.615
39.0	4.630	43.9	5.140	48.9	5.695	54.3	6.300	60.9	7.040	64.2	7.640
39.4	4.650	44.2	5.155	48.9	5.715	54.1	6.320	62.4	7.075	64.2	7.650
39.7	4.660	44.3	5.175	49.4	5.725	54.4	6.330	62.5	7.090	64.4	7.670
39.2	4.670	44.3	5.180	49.7	5.755	54.6	6.350	62.2	7.115	64.4	7.685
39.7	4.680	44.1	5.195	49.9	5.765	54.9	6.370	62.6	7.130	64.5	7.700
39.5	4.690	44.4	5.205	50.1	5.785	55.2	6.380	62.2	7.145	64.1	7.710
39.5	4.700	44.1	5.210	50.2	5.795	54.9	6.395	62.1	7.150	64.4	7.725
39.5	4.710	44.4	5.225	49.7	5.805	54.2	6.400	62.0	7.170	64.9	7.740
39.9	4.720	44.7	5.245	50.2	5.815	55.5	6.425	62.4	7.185	64.9	7.760
39.7	4.725	44.5	5.250	50.3	5.835	55.8	6.445	62.3	7.200	65.3	7.775
39.5	4.735	45.1	5.270	50.4	5.845	56.4	6.470	62.5	7.220	65.3	7.790
39.3	4.740	45.4	5.285	50.9	5.865	56.8	6.490	62.4	7.230	64.7	7.800
40.3	4.765	45.1	5.300	50.8	5.875	57.1	6.510	62.0	7.240	65.6	7.820
40.6	4.780	45.2	5.310	50.6	5.890	56.7	6.525	62.1	7.255	65.8	7.835
41.2	4.795	45.6	5.320	50.8	5.900	57.2	6.545	62.4	7.270	65.7	7.850
41.7	4.820	45.2	5.325	50.6	5.915	57.4	6.560	62.5	7.285	66.4	7.865
41.5	4.830	45.5	5.340	50.2	5.925	57.7	6.585	62.8	7.300	65.9	7.875
41.8	4.855	45.8	5.350	50.8	5.940	58.2	6.605	62.5	7.315	65.8	7.895
41.4	4.860	45.8	5.370	51.4	5.955	58.2	6.625	62.7	7.325	66.0	7.905
41.0	4.870	46.0	5.380	51.4	5.975	58.0	6.635	62.1	7.335	66.4	7.925
41.5	4.880	46.3	5.405	51.6	5.985	57.7	6.650	62.7	7.350	66.5	7.945
41.0	4.890	46.4	5.415	51.7	6.000	58.6	6.670	62.9	7.365	66.7	7.955
41.3	4.900	46.1	5.430	51.6	6.015	58.5	6.695	63.0	7.385	66.5	7.965
41.6	4.910	46.1	5.435	51.8	6.030	59.4	6.715	63.4	7.405	66.0	7.975
41.7	4.920	46.1	5.450	51.9	6.040	59.3	6.745	63.0	7.415	67.0	8.005
41.4	4.930	46.6	5.460	51.3	6.050	59.6	6.755	62.8	7.425	67.5	8.025
41.3	4.940	46.4	5.475	52.2	6.070	58.9	6.775	63.6	7.435	67.5	8.045
41.1	4.950	46.6	5.485	52.7	6.090	58.6	6.780	63.8	7.460	67.5	8.055
41.4	4.960	46.9	5.505	53.1	6.105	60.0	6.815	63.7	7.475	67.2	8.065
41.7	4.970	47.4	5.520	53.0	6.130	60.5	6.835	64.0	7.490	68.4	8.095
41.3	4.970	47.8	5.540	53.9	6.140	60.6	6.860	63.9	7.500	68.8	8.125
42.2	4.990	48.3	5.560	53.5	6.160	60.5	6.870	63.8	7.515	69.0	8.140

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
68.8	8.155	74.6	8.905	80.7	9.760	83.7	10.685	84.4	11.845	61.6	12.695
68.6	8.165	74.3	8.920	80.7	9.780	83.8	10.715	85.1	11.895	60.8	12.705
69.0	8.190	74.2	8.940	81.0	9.810	84.9	10.740	84.7	11.930	60.5	12.720
69.6	8.205	74.3	8.960	81.6	9.830	84.7	10.765	83.9	11.955	60.1	12.735
69.5	8.225	74.6	8.975	81.5	9.860	84.2	10.780	83.7	12.005	59.9	12.745
69.6	8.240	74.6	8.995	81.6	9.870	83.9	10.805	83.5	12.035	59.4	12.760
69.4	8.260	74.4	9.000	80.7	9.890	84.5	10.830	82.2	12.065	58.7	12.770
69.3	8.270	74.4	9.025	81.1	9.910	84.3	10.855	81.2	12.095	58.6	12.790
69.9	8.290	75.0	9.045	81.3	9.935	84.5	10.875	81.8	12.150	58.3	12.800
70.1	8.310	75.7	9.070	81.1	9.950	83.7	10.900	81.2	12.175	57.9	12.815
70.3	8.330	75.5	9.090	81.3	9.970	84.6	10.920	79.8	12.205	58.2	12.830
70.1	8.340	75.4	9.110	81.1	9.990	84.4	10.950	78.6	12.220	57.7	12.845
69.4	8.350	76.1	9.130	82.0	10.025	84.5	10.970	77.5	12.250	57.6	12.855
70.0	8.370	76.3	9.155	82.3	10.045	83.8	10.990	77.1	12.265	57.3	12.875
70.2	8.390	76.3	9.175	82.0	10.070	84.7	11.020	75.8	12.295	56.9	12.880
70.6	8.410	76.1	9.190	81.4	10.075	85.3	11.060	75.4	12.315	56.3	12.900
70.7	8.430	76.0	9.200	81.7	10.105	85.2	11.080	73.7	12.335	56.6	12.915
70.3	8.440	76.6	9.230	82.0	10.125	84.0	11.095	73.2	12.350	56.2	12.935
71.0	8.470	76.8	9.250	82.0	10.145	84.4	11.120	71.9	12.365	56.0	12.955
72.1	8.490	76.8	9.270	82.1	10.165	84.6	11.145	71.6	12.380	55.9	12.970
71.9	8.515	76.5	9.280	81.7	10.185	84.8	11.175	70.5	12.395	55.4	12.985
71.7	8.530	76.9	9.305	82.4	10.205	84.2	11.195	70.1	12.410	55.5	13.005
71.4	8.540	77.2	9.325	82.9	10.240	84.6	11.215	69.0	12.420	55.6	13.025
71.7	8.555	77.8	9.355	82.8	10.255	85.2	11.260	68.5	12.435	55.9	13.055
72.2	8.580	77.8	9.370	82.4	10.275	85.1	11.280	67.9	12.455	55.7	13.075
72.2	8.600	77.0	9.390	82.4	10.295	84.3	11.305	67.4	12.470	54.4	13.110
72.2	8.620	78.1	9.410	82.9	10.320	85.8	11.345	66.9	12.485	53.3	13.125
71.8	8.630	78.8	9.445	83.2	10.345	86.5	11.390	66.5	12.495	52.5	13.140
72.2	8.645	78.7	9.465	82.6	10.365	86.2	11.420	65.5	12.510	52.2	13.160
72.5	8.665	78.3	9.475	82.9	10.385	85.5	11.440	65.3	12.520	51.3	13.185
72.9	8.695	79.2	9.505	83.8	10.425	86.2	11.480	64.7	12.535	51.0	13.200
73.4	8.715	79.9	9.535	84.0	10.445	85.9	11.515	64.6	12.550	50.6	13.235
72.7	8.725	79.9	9.555	83.4	10.465	85.6	11.540	64.1	12.560	50.3	13.250
73.0	8.745	79.4	9.575	84.2	10.495	84.7	11.560	63.9	12.575	50.1	13.285
73.9	8.775	79.4	9.595	85.7	10.540	85.9	11.605	63.3	12.595	50.4	13.320
74.0	8.790	80.1	9.620	85.4	10.565	86.0	11.650	63.0	12.605	49.9	13.360
74.0	8.810	80.0	9.635	84.6	10.580	85.1	11.670	62.9	12.620	49.7	13.385
73.4	8.820	80.0	9.665	84.7	10.600	84.7	11.700	62.2	12.630	48.4	13.410
74.5	8.850	79.5	9.670	84.8	10.630	85.3	11.740	61.8	12.645		
74.4	8.870	80.3	9.710	84.3	10.650	84.9	11.780	61.6	12.660		
74.6	8.890	81.1	9.730	84.2	10.670	83.9	11.800	61.5	12.680		

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Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
0.0	0.000	9.5	1.770	21.4	3.410	31.4	4.625	37.9	5.385	44.2	6.105
0.0	0.035	9.9	1.810	21.8	3.450	31.9	4.650	38.1	5.410	44.0	6.130
0.3	0.095	10.5	1.845	22.3	3.490	32.5	4.675	38.3	5.425	44.3	6.150
0.4	0.135	10.8	1.905	22.8	3.540	32.3	4.705	38.1	5.435	44.1	6.160
0.4	0.195	11.2	1.945	23.0	3.575	32.2	4.720	38.7	5.455	43.9	6.170
0.5	0.280	11.9	2.005	23.0	3.620	32.2	4.735	39.2	5.485	44.2	6.190
0.5	0.290	12.1	2.035	23.0	3.630	32.1	4.745	39.6	5.510	43.5	6.190
0.6	0.395	11.9	2.070	23.5	3.675	32.9	4.785	40.0	5.545	44.3	6.215
0.6	0.425	12.6	2.110	23.9	3.705	33.1	4.810	40.0	5.555	44.7	6.230
1.0	0.495	13.0	2.165	24.0	3.755	33.5	4.845	39.6	5.570	44.8	6.250
1.2	0.555	13.6	2.215	24.7	3.780	33.8	4.865	39.4	5.580	45.3	6.270
1.3	0.595	13.5	2.250	24.8	3.830	33.5	4.880	40.0	5.610	44.9	6.275
1.5	0.650	13.4	2.260	24.5	3.840	33.6	4.890	40.6	5.630	45.0	6.285
1.6	0.695	13.9	2.310	25.3	3.885	33.5	4.905	40.6	5.650	44.6	6.300
1.8	0.750	14.6	2.360	25.8	3.925	33.8	4.930	40.6	5.670	44.8	6.315
2.2	0.820	15.1	2.425	26.3	3.975	34.5	4.955	40.9	5.700	45.0	6.335
2.3	0.825	15.3	2.475	26.4	4.005	34.7	4.975	40.9	5.710	45.0	6.345
2.5	0.885	15.1	2.505	26.4	4.035	34.4	4.995	41.4	5.745	45.0	6.360
2.6	0.925	15.4	2.550	26.7	4.055	34.7	5.005	42.0	5.765	45.0	6.370
3.1	0.965	15.9	2.605	26.8	4.090	34.7	5.015	42.4	5.795	45.1	6.385
3.1	0.990	16.4	2.650	27.0	4.110	34.2	5.025	42.7	5.815	45.0	6.395
3.5	1.055	16.7	2.710	27.3	4.150	34.3	5.045	42.6	5.840	45.4	6.410
3.8	1.090	16.7	2.725	27.9	4.175	35.0	5.065	42.3	5.855	45.7	6.425
4.2	1.130	17.0	2.780	27.9	4.215	34.8	5.080	42.3	5.875	45.8	6.445
4.6	1.170	17.2	2.820	27.8	4.225	35.5	5.100	42.6	5.890	46.0	6.460
5.0	1.230	17.9	2.870	29.2	4.280	35.5	5.120	42.4	5.910	46.1	6.475
5.1	1.255	18.2	2.910	29.0	4.310	35.4	5.140	42.7	5.925	46.1	6.490
5.3	1.295	18.1	2.955	29.5	4.355	35.7	5.155	42.8	5.950	45.8	6.500
5.9	1.340	18.2	2.980	29.9	4.385	35.7	5.165	43.2	5.960	45.8	6.510
6.1	1.395	19.2	3.040	29.5	4.405	36.4	5.205	42.5	5.970	45.7	6.525
6.6	1.425	19.3	3.080	29.5	4.420	37.2	5.225	42.6	5.985	45.7	6.530
6.9	1.470	20.0	3.140	30.1	4.455	37.1	5.255	43.1	6.010	45.8	6.550
7.4	1.505	20.1	3.175	30.4	4.480	37.3	5.270	43.0	6.020	45.8	6.560
7.7	1.565	19.9	3.205	30.8	4.520	37.1	5.290	42.7	6.035	45.9	6.575
8.2	1.605	20.2	3.255	30.8	4.540	37.0	5.305	43.1	6.045	46.1	6.580
8.2	1.635	21.0	3.300	31.0	4.560	37.2	5.320	42.8	6.060	45.7	6.595
8.7	1.675	21.3	3.340	30.7	4.575	37.5	5.340	43.2	6.070	46.0	6.600
9.3	1.730	21.5	3.390	30.9	4.600	38.1	5.370	42.6	6.085	46.6	6.630

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
46.8	6.640	48.8	7.110	51.4	7.555	55.6	8.095	59.0	8.645	62.9	9.220
46.6	6.660	49.0	7.125	51.9	7.575	55.8	8.110	59.3	8.665	62.7	9.240
46.8	6.670	48.5	7.130	51.8	7.585	56.2	8.125	59.5	8.685	62.9	9.255
46.8	6.680	49.0	7.140	52.0	7.595	56.3	8.140	59.6	8.695	62.7	9.270
46.9	6.685	48.7	7.150	51.7	7.605	56.3	8.150	59.7	8.715	62.4	9.275
46.6	6.705	48.7	7.160	51.9	7.620	55.8	8.160	59.4	8.725	62.6	9.290
46.9	6.715	48.7	7.170	52.2	7.630	55.9	8.170	59.4	8.735	62.9	9.305
47.4	6.735	49.2	7.190	52.3	7.645	56.3	8.190	59.7	8.755	63.0	9.325
47.0	6.745	49.5	7.200	52.5	7.655	56.8	8.210	60.0	8.770	63.1	9.335
47.2	6.755	49.3	7.210	52.3	7.675	57.1	8.230	60.3	8.785	63.3	9.355
47.5	6.765	49.5	7.220	52.5	7.680	57.0	8.240	60.5	8.795	63.5	9.365
47.2	6.785	49.5	7.230	52.4	7.690	56.8	8.255	60.0	8.810	63.4	9.380
47.4	6.790	49.6	7.240	52.1	7.695	56.5	8.255	59.8	8.815	63.4	9.395
47.2	6.800	49.2	7.250	52.5	7.725	56.8	8.275	59.9	8.835	63.7	9.415
47.2	6.810	49.3	7.255	52.9	7.735	56.8	8.285	60.3	8.850	63.9	9.425
47.5	6.825	49.4	7.270	53.0	7.750	57.1	8.305	60.6	8.870	63.8	9.440
47.7	6.835	49.6	7.280	53.5	7.760	57.2	8.315	60.8	8.880	63.8	9.450
47.5	6.850	49.9	7.295	53.4	7.780	57.2	8.330	60.6	8.895	63.6	9.465
47.8	6.860	49.9	7.305	53.6	7.785	57.4	8.345	60.4	8.900	63.7	9.480
47.7	6.870	50.1	7.320	53.3	7.800	57.1	8.365	60.7	8.920	64.1	9.500
47.7	6.885	50.1	7.330	53.7	7.810	57.3	8.375	60.9	8.940	64.5	9.515
47.8	6.895	49.9	7.335	53.7	7.830	57.5	8.390	61.1	8.955	64.5	9.535
48.1	6.910	50.0	7.345	54.1	7.840	57.4	8.405	61.4	8.970	64.5	9.545
47.9	6.925	50.2	7.360	54.3	7.860	58.0	8.420	61.6	8.985	64.2	9.555
48.1	6.935	50.3	7.370	54.1	7.870	58.1	8.435	61.4	8.995	64.6	9.575
47.9	6.945	50.4	7.390	53.9	7.880	57.7	8.440	60.7	9.000	64.9	9.595
48.0	6.955	50.6	7.400	54.1	7.890	58.2	8.465	61.3	9.020	64.8	9.610
47.9	6.965	50.8	7.415	54.4	7.905	58.2	8.480	61.3	9.035	65.3	9.630
47.7	6.975	50.8	7.420	54.2	7.915	58.5	8.490	61.7	9.050	65.4	9.640
48.0	6.985	50.5	7.430	54.6	7.935	58.6	8.515	61.8	9.070	64.5	9.655
48.1	7.000	50.6	7.440	54.6	7.945	58.5	8.525	61.7	9.080	64.6	9.665
48.3	7.010	50.8	7.450	54.9	7.970	58.5	8.535	61.4	9.090	65.5	9.690
48.4	7.025	50.9	7.460	54.2	7.970	58.0	8.540	61.6	9.100	65.2	9.700
48.3	7.035	50.7	7.475	55.3	7.995	58.6	8.555	62.0	9.115	65.8	9.725
48.5	7.045	51.0	7.485	55.4	8.010	59.0	8.570	61.8	9.135	65.5	9.735
48.4	7.055	50.9	7.495	55.7	8.035	58.9	8.585	62.0	9.155	65.5	9.750
48.7	7.065	51.3	7.505	55.8	8.045	58.9	8.600	62.3	9.165	65.8	9.760
48.4	7.075	50.6	7.515	55.6	8.060	59.0	8.620	62.1	9.180	65.4	9.780
48.7	7.090	51.0	7.530	55.6	8.070	59.3	8.625	61.7	9.185	65.7	9.795
48.8	7.100	51.4	7.545	55.4	8.080	58.7	8.635	62.5	9.205	65.9	9.810

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
66.0	9.820	69.2	10.450	74.0	11.220	77.5	12.185	71.7	13.385		
65.6	9.840	68.8	10.470	74.4	11.240	76.5	12.210	72.0	13.425		
65.6	9.850	68.8	10.475	73.5	11.245	76.4	12.225	71.9	13.445		
65.9	9.870	69.0	10.495	74.4	11.275	76.5	12.260	70.7	13.470		
66.0	9.880	69.2	10.510	75.0	11.305	77.4	12.295	71.6	13.510		
66.2	9.905	69.5	10.530	75.1	11.330	77.7	12.325	72.0	13.555		
66.6	9.920	69.6	10.545	74.9	11.345	77.0	12.340	71.3	13.580		
65.9	9.930	69.5	10.560	74.3	11.365	77.5	12.380	70.3	13.610		
66.2	9.940	70.1	10.575	74.5	11.385	78.2	12.410	71.5	13.650		
66.7	9.965	70.1	10.600	75.0	11.415	77.8	12.440	72.3	13.715		
66.8	9.980	70.6	10.615	75.0	11.440	76.6	12.455	71.8	13.740		
67.0	10.000	70.4	10.640	74.4	11.450	76.7	12.485	71.2	13.785		
66.6	10.010	70.3	10.655	74.8	11.475	76.9	12.505	72.6	13.835		
66.5	10.020	70.7	10.675	75.5	11.505	77.4	12.540	71.6	13.890		
66.8	10.035	71.2	10.695	75.2	11.525	76.4	12.555	70.5	13.915		
67.2	10.060	71.4	10.720	75.2	11.545	76.9	12.595	71.1	13.975		
67.3	10.075	71.9	10.740	74.5	11.555	78.2	12.635	71.4	14.030		
67.3	10.095	71.6	10.750	75.6	11.585	77.5	12.670	70.2	14.080		
67.4	10.100	71.3	10.770	75.7	11.610	76.5	12.680	70.0	14.115		
67.4	10.115	72.0	10.800	75.5	11.640	77.7	12.730	71.3	14.215		
67.5	10.130	72.1	10.820	75.4	11.650	77.7	12.760	69.8	14.255		
67.9	10.150	72.4	10.840	75.8	11.680	77.5	12.790	68.0	14.295		
68.0	10.165	72.3	10.855	77.3	11.720	76.3	12.805	68.8	14.365		
68.2	10.185	71.8	10.870	77.3	11.760	77.0	12.855	68.9	14.445		
67.7	10.195	71.7	10.890	76.9	11.770	77.4	12.895	66.5	14.470		
67.6	10.210	72.4	10.910	76.6	11.800	77.1	12.925	66.3	14.545		
68.1	10.225	72.2	10.930	77.4	11.830	76.1	12.935	66.4	14.600		
68.1	10.245	72.4	10.950	77.2	11.860	76.7	12.985	64.3	14.665		
68.3	10.255	72.1	10.955	76.8	11.880	77.5	13.025	63.0	14.695		
68.5	10.275	72.4	10.985	76.5	11.900	76.5	13.060	64.3	14.800		
67.7	10.285	72.3	11.000	76.6	11.920	75.6	13.085	63.5	14.855		
67.9	10.300	72.8	11.025	76.9	11.955	77.9	13.150	61.0	14.905		
68.0	10.315	72.6	11.040	77.0	11.975	78.1	13.190	61.4	14.975		
68.3	10.335	72.8	11.065	76.0	11.990	76.4	13.215	60.8	15.070		
68.5	10.350	72.6	11.085	77.1	12.020	75.6	13.235	58.4	15.100		
68.6	10.365	73.9	11.115	78.1	12.070	74.7	13.270	57.5	15.170		
68.3	10.375	73.8	11.135	77.5	12.090	74.8	13.295				
68.7	10.400	73.4	11.150	76.8	12.110	73.8	13.325				
69.2	10.415	73.4	11.165	77.6	12.135	72.5	13.340				
69.2	10.435	73.5	11.195	77.3	12.165	71.8	13.360				

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Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
0.0	0.000	10.5	1.850	19.8	2.775	25.3	3.505	30.0	4.060	33.4	4.550
0.1	0.140	11.0	1.875	19.9	2.810	25.4	3.515	29.9	4.065	33.9	4.560
0.2	0.180	11.4	1.905	20.3	2.825	26.0	3.535	30.0	4.075	33.6	4.570
0.4	0.310	11.8	1.925	20.7	2.850	25.8	3.545	30.6	4.095	33.6	4.580
0.5	0.340	12.0	1.950	20.5	2.880	25.6	3.555	30.8	4.115	33.7	4.590
0.6	0.480	12.2	1.980	21.0	2.910	25.9	3.565	31.2	4.140	33.4	4.595
0.7	0.520	12.4	2.015	21.0	2.925	26.5	3.580	31.5	4.160	33.9	4.610
0.7	0.625	12.6	2.030	21.1	2.955	26.2	3.600	31.6	4.170	33.7	4.620
1.0	0.705	13.2	2.055	21.7	2.975	26.5	3.610	31.7	4.180	33.9	4.630
1.3	0.765	13.1	2.075	21.6	2.995	26.6	3.620	31.5	4.195	33.9	4.630
1.2	0.855	13.4	2.100	21.0	3.010	26.6	3.635	31.0	4.200	34.1	4.640
1.7	0.895	13.4	2.115	21.3	3.025	26.7	3.645	31.5	4.215	33.7	4.645
1.8	0.940	13.7	2.140	21.9	3.045	26.8	3.655	31.8	4.225	34.1	4.655
2.4	1.000	13.5	2.155	22.3	3.070	27.3	3.675	32.5	4.255	34.4	4.675
2.5	1.020	14.3	2.185	22.2	3.090	27.5	3.690	32.3	4.270	34.9	4.695
2.8	1.085	14.4	2.200	23.0	3.125	27.2	3.700	32.4	4.280	35.0	4.705
3.1	1.130	14.6	2.220	22.7	3.145	27.4	3.710	32.6	4.290	35.0	4.725
3.4	1.150	14.5	2.230	23.3	3.170	27.5	3.720	32.8	4.305	34.9	4.725
4.0	1.185	14.6	2.265	22.9	3.180	27.6	3.740	32.2	4.310	35.3	4.745
4.2	1.230	15.1	2.285	22.9	3.200	27.9	3.760	32.1	4.320	35.1	4.750
4.3	1.265	15.2	2.305	22.8	3.200	28.0	3.775	32.2	4.330	35.6	4.755
4.6	1.285	15.4	2.330	23.2	3.225	28.0	3.785	32.5	4.340	35.5	4.775
4.8	1.310	15.6	2.355	23.6	3.245	27.9	3.795	32.3	4.350	35.6	4.790
5.3	1.350	16.1	2.375	23.8	3.265	28.3	3.810	32.4	4.360	36.2	4.810
5.5	1.385	16.4	2.405	23.8	3.280	28.7	3.830	32.9	4.380	36.2	4.830
6.4	1.435	16.5	2.420	24.0	3.300	28.6	3.850	33.0	4.405	36.2	4.845
6.5	1.450	16.2	2.440	24.2	3.320	29.4	3.880	33.1	4.415	36.4	4.855
6.7	1.480	16.8	2.455	24.6	3.335	29.9	3.900	33.2	4.425	35.3	4.865
6.9	1.510	16.9	2.485	24.7	3.350	29.4	3.915	33.1	4.435	35.7	4.870
7.5	1.555	16.6	2.495	24.6	3.365	29.5	3.925	32.9	4.440	36.5	4.885
7.6	1.585	17.5	2.520	24.7	3.375	29.6	3.935	33.3	4.455	36.6	4.905
8.5	1.625	17.4	2.545	24.9	3.395	29.6	3.955	33.4	4.470	36.5	4.915
8.2	1.645	18.1	2.585	24.9	3.410	29.9	3.970	33.5	4.485	36.9	4.935
8.8	1.680	18.1	2.605	24.9	3.420	30.2	3.990	33.5	4.495	37.2	4.950
8.9	1.710	18.3	2.630	25.3	3.435	30.3	4.010	34.0	4.505	37.0	4.965
9.7	1.750	18.5	2.645	25.2	3.460	30.5	4.020	33.9	4.520	37.2	4.975
9.9	1.780	19.2	2.685	25.6	3.470	30.6	4.035	33.9	4.530	36.9	4.985
10.5	1.815	19.2	2.710	25.7	3.485	30.2	4.040	34.0	4.540	37.1	4.990
10.6	1.825	19.3	2.745	25.8	3.495	30.2	4.050	33.9	4.550	37.6	5.010

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
37.7	5.030	40.7	5.500	43.1	5.925	45.4	6.370	48.6	6.790	52.6	7.265
38.0	5.050	40.5	5.505	43.3	5.940	45.6	6.380	48.5	6.800	52.7	7.275
38.3	5.065	40.9	5.520	43.1	5.950	45.7	6.390	48.5	6.810	52.8	7.290
38.1	5.080	41.4	5.540	43.3	5.960	45.2	6.400	48.7	6.825	52.7	7.300
38.0	5.085	41.3	5.560	43.1	5.970	45.3	6.410	49.0	6.835	53.0	7.310
38.1	5.100	41.5	5.575	43.1	5.975	45.4	6.420	48.9	6.850	52.8	7.325
37.4	5.105	41.7	5.580	43.3	5.990	45.6	6.420	48.8	6.860	52.6	7.330
37.9	5.115	41.4	5.595	43.8	6.010	45.3	6.430	48.9	6.865	53.3	7.350
38.1	5.125	41.3	5.605	44.0	6.020	45.7	6.440	49.1	6.875	53.3	7.360
38.0	5.140	41.3	5.615	44.2	6.035	45.2	6.450	48.5	6.885	53.2	7.375
38.2	5.155	41.1	5.615	44.1	6.050	45.9	6.460	49.1	6.895	53.8	7.385
38.2	5.165	41.4	5.635	44.3	6.060	45.8	6.470	49.5	6.915	53.7	7.395
38.4	5.175	41.6	5.645	44.4	6.070	46.0	6.480	49.3	6.925	53.6	7.405
38.5	5.190	41.5	5.655	44.1	6.080	46.2	6.490	50.0	6.935	53.3	7.415
38.8	5.195	41.4	5.665	44.6	6.100	46.1	6.500	49.8	6.945	53.7	7.425
38.4	5.205	41.9	5.675	44.9	6.120	46.1	6.515	49.8	6.960	53.9	7.445
39.0	5.230	41.4	5.685	45.3	6.130	46.3	6.520	50.4	6.965	53.9	7.455
39.0	5.240	41.3	5.695	45.6	6.150	46.3	6.530	49.8	6.975	54.0	7.465
39.0	5.250	41.3	5.700	45.0	6.155	46.7	6.545	50.1	6.990	54.2	7.480
38.9	5.260	41.4	5.700	45.1	6.170	46.8	6.555	50.2	7.005	54.3	7.495
39.2	5.270	41.6	5.715	44.9	6.175	47.1	6.565	50.7	7.015	54.1	7.500
39.2	5.285	41.7	5.725	45.1	6.190	47.1	6.585	50.4	7.030	54.5	7.515
39.1	5.290	42.3	5.735	45.2	6.200	47.3	6.595	50.5	7.040	54.8	7.530
39.0	5.300	42.1	5.755	45.8	6.215	47.1	6.605	50.9	7.050	54.9	7.545
38.6	5.305	42.3	5.765	45.0	6.225	47.3	6.615	50.5	7.060	55.1	7.560
39.3	5.325	42.4	5.775	45.5	6.235	47.4	6.620	51.3	7.080	55.2	7.570
39.1	5.330	42.4	5.785	45.5	6.245	47.3	6.635	51.1	7.090	55.2	7.580
39.2	5.345	42.2	5.795	45.1	6.255	48.2	6.655	51.6	7.110	55.1	7.590
39.5	5.355	42.0	5.800	45.4	6.265	48.1	6.665	51.7	7.120	55.2	7.600
39.5	5.365	42.3	5.815	44.9	6.265	48.0	6.675	51.7	7.135	55.2	7.620
39.2	5.375	42.5	5.825	44.9	6.275	48.1	6.685	51.8	7.140	55.6	7.630
39.3	5.385	42.6	5.835	45.5	6.285	48.2	6.695	51.7	7.155	55.9	7.650
38.9	5.385	42.7	5.845	45.4	6.295	47.8	6.700	52.2	7.165	56.0	7.660
38.8	5.395	42.6	5.855	45.5	6.310	47.7	6.710	52.0	7.180	55.9	7.670
39.5	5.405	42.6	5.865	45.5	6.315	48.3	6.720	52.0	7.195	55.7	7.680
40.0	5.430	42.4	5.870	45.5	6.330	48.4	6.740	52.4	7.205	55.8	7.695
40.3	5.445	42.2	5.880	45.4	6.335	48.5	6.750	52.5	7.215	56.2	7.705
40.5	5.465	42.4	5.885	45.2	6.345	48.5	6.760	52.2	7.225	56.3	7.720
40.6	5.475	42.6	5.900	45.1	6.350	48.7	6.770	52.2	7.230	56.4	7.730
40.8	5.490	43.1	5.915	45.1	6.360	48.8	6.790	52.3	7.255	56.6	7.750

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
56.3	7.755	61.7	8.320	67.5	8.990	72.8	9.685	80.5	10.565	83.6	11.590
56.5	7.765	61.8	8.335	68.0	9.015	72.9	9.695	80.1	10.590	83.6	11.610
56.6	7.780	62.1	8.355	68.1	9.035	73.4	9.720	79.9	10.610	81.1	11.630
56.7	7.795	62.3	8.370	68.2	9.055	73.9	9.745	79.8	10.630	83.2	11.655
57.0	7.805	62.4	8.385	67.4	9.055	74.9	9.780	80.6	10.660	83.7	11.690
57.2	7.825	62.3	8.395	67.8	9.080	74.7	9.795	80.6	10.685	84.5	11.715
57.1	7.835	62.8	8.425	68.1	9.095	74.3	9.820	80.6	10.705	82.3	11.725
57.1	7.845	62.9	8.445	68.6	9.120	74.7	9.835	79.6	10.725	83.9	11.770
56.6	7.855	63.2	8.460	68.6	9.135	75.1	9.865	80.3	10.750	84.9	11.820
57.6	7.875	63.5	8.475	67.9	9.145	75.2	9.885	82.4	10.800	84.0	11.840
57.8	7.885	63.3	8.485	68.3	9.160	74.7	9.900	82.0	10.820	83.2	11.860
57.9	7.905	63.5	8.500	68.5	9.180	74.8	9.915	81.0	10.840	84.6	11.900
58.3	7.915	63.7	8.520	68.7	9.195	76.4	9.955	81.0	10.860	85.4	11.955
57.7	7.930	63.9	8.535	68.7	9.215	76.1	9.975	81.0	10.885	86.2	11.975
57.8	7.940	63.9	8.555	69.1	9.230	76.3	9.995	81.1	10.905	84.7	12.010
58.0	7.955	63.2	8.570	68.6	9.240	75.5	10.005	80.9	10.925	86.3	12.055
58.6	7.965	63.4	8.585	69.2	9.260	76.8	10.045	80.5	10.935	85.5	12.100
58.8	7.990	63.5	8.595	69.1	9.285	77.1	10.065	80.9	10.965	84.3	12.110
59.5	8.010	63.8	8.615	69.4	9.300	76.8	10.095	82.4	11.005	86.3	12.180
59.5	8.020	63.9	8.625	69.7	9.315	76.7	10.105	82.0	11.035	85.8	12.215
59.1	8.030	64.2	8.645	69.3	9.325	76.8	10.130	81.6	11.045	84.7	12.250
59.1	8.045	64.3	8.665	70.2	9.355	77.0	10.150	81.6	11.075	84.1	12.270
59.6	8.060	64.0	8.675	71.5	9.390	76.9	10.170	82.4	11.105	85.9	12.340
59.9	8.080	64.2	8.690	71.7	9.410	76.9	10.190	82.2	11.135	85.5	12.380
59.8	8.090	64.3	8.715	71.6	9.430	76.3	10.205	82.0	11.150	83.8	12.410
60.1	8.110	65.0	8.730	71.1	9.440	76.3	10.225	82.3	11.190	85.7	12.470
59.9	8.120	65.2	8.750	71.4	9.450	77.2	10.255	84.0	11.230	85.5	12.525
60.1	8.140	65.4	8.760	71.2	9.470	77.6	10.270	83.6	11.255	84.5	12.545
60.4	8.150	64.9	8.780	71.6	9.490	77.1	10.290	82.6	11.265	83.5	12.585
60.6	8.170	65.0	8.790	71.2	9.510	76.8	10.295	83.2	11.305	83.7	12.620
61.1	8.190	65.9	8.820	71.4	9.520	77.7	10.335	83.5	11.335	83.6	12.670
61.0	8.200	66.0	8.830	71.4	9.540	77.1	10.365	83.3	11.360	82.6	12.695
61.0	8.210	66.0	8.850	71.5	9.550	78.4	10.390	82.8	11.375	82.0	12.730
61.2	8.230	65.8	8.860	71.7	9.575	77.9	10.400	83.4	11.410	83.8	12.795
61.3	8.245	66.4	8.890	71.9	9.590	79.1	10.440	84.4	11.450	83.3	12.840
61.6	8.265	66.7	8.915	71.7	9.610	79.7	10.465	84.2	11.485	81.5	12.855
61.5	8.280	67.5	8.940	71.6	9.620	79.6	10.490	83.5	11.500	83.2	12.930
61.6	8.295	67.6	8.955	72.3	9.650	79.2	10.505	83.2	11.525	83.1	12.975
61.6	8.300	67.1	8.970	72.8	9.670	79.8	10.535	83.6	11.555	80.9	13.000

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
81.2	13.045	52.9	15.595								
82.1	13.110	52.0	15.760								
81.1	13.145	48.0	15.810								
79.8	13.180	48.7	16.025								
80.8	13.235	46.1	16.120								
80.5	13.295										
79.0	13.315										
79.2	13.370										
79.4	13.420										
78.1	13.465										
76.3	13.480										
76.9	13.545										
77.2	13.590										
75.7	13.630										
74.9	13.660										
76.0	13.725										
75.4	13.765										
73.2	13.795										
75.3	13.865										
74.9	13.935										
73.0	13.955										
75.7	14.065										
75.3	14.130										
73.3	14.180										
73.9	14.235										
71.8	14.300										
69.9	14.330										
71.9	14.450										
69.0	14.475										
69.5	14.580										
69.0	14.655										
66.5	14.730										
66.3	14.815										
61.7	14.860										
63.5	14.970										
60.3	15.060										
58.8	15.130										
59.0	15.290										
56.5	15.345										
55.8	15.525										

Experimental data from the masonry wallettes tested at 800ºC.

Wallette 14

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
0.0	0.000	6.9	0.915	11.1	1.877	13.9	3.083	15.2	4.231	17.4	5.669
0.3	0.024	7.0	0.940	11.1	1.907	13.5	3.100	14.8	4.260	17.3	5.712
0.5	0.052	7.3	0.968	10.7	1.926	13.3	3.127	15.3	4.295	17.2	5.767
0.6	0.072	7.0	0.987	11.1	1.951	13.3	3.151	15.1	4.335	17.4	5.808
0.8	0.094	7.1	1.012	11.1	1.975	13.1	3.179	15.1	4.365	17.3	5.850
0.9	0.118	7.2	1.035	11.0	2.009	13.4	3.209	15.2	4.402	16.9	5.889
1.3	0.141	7.5	1.062	11.7	2.041	13.3	3.238	15.0	4.438	17.1	5.930
1.6	0.168	7.6	1.083	11.7	2.085	13.6	3.270	15.3	4.476	16.9	5.966
1.6	0.183	7.7	1.107	11.7	2.116	13.5	3.311	15.0	4.504	17.3	6.016
1.8	0.206	7.9	1.136	11.7	2.153	13.5	3.330	15.0	4.542	17.5	6.065
1.8	0.227	7.9	1.159	12.0	2.181	13.6	3.359	15.0	4.580	17.9	6.130
2.6	0.256	8.0	1.182	12.3	2.216	13.3	3.385	15.2	4.621	17.4	6.158
2.2	0.281	7.9	1.204	12.1	2.249	13.2	3.413	15.3	4.652	17.8	6.202
2.9	0.311	8.1	1.226	12.3	2.289	13.3	3.437	15.1	4.688	17.8	6.249
3.1	0.330	8.4	1.256	12.5	2.327	13.8	3.471	14.7	4.715	18.0	6.309
2.9	0.353	8.3	1.279	12.3	2.358	13.8	3.511	15.3	4.758	17.7	6.347
3.3	0.366	8.7	1.306	12.9	2.393	14.2	3.552	15.2	4.788	18.0	6.394
3.2	0.389	8.8	1.337	13.0	2.437	14.0	3.574	15.3	4.824	18.1	6.434
3.6	0.414	9.1	1.372	12.6	2.465	13.8	3.605	15.4	4.862	17.9	6.483
4.0	0.452	8.9	1.391	12.9	2.502	13.9	3.634	15.6	4.911	18.1	6.526
3.9	0.480	9.2	1.412	13.1	2.534	13.8	3.669	15.7	4.947	18.4	6.572
4.1	0.502	9.0	1.436	13.1	2.574	14.2	3.697	15.9	4.978	18.3	6.619
4.5	0.529	9.0	1.463	13.1	2.608	13.8	3.730	16.0	5.023	18.2	6.663
4.5	0.553	9.2	1.486	12.9	2.635	14.1	3.760	16.1	5.075	17.7	6.703
4.5	0.574	9.1	1.510	13.0	2.664	13.5	3.783	16.5	5.110	18.1	6.750
4.5	0.597	9.5	1.538	13.1	2.704	13.8	3.810	16.1	5.155	18.5	6.805
4.7	0.625	9.7	1.575	13.3	2.736	14.0	3.843	16.4	5.191	18.4	6.859
5.3	0.657	9.9	1.602	13.2	2.767	14.1	3.875	16.6	5.246	18.2	6.882
5.7	0.686	9.9	1.628	13.5	2.796	14.2	3.917	16.5	5.281	18.6	6.938
5.4	0.707	10.1	1.653	13.5	2.838	14.3	3.950	16.7	5.321	19.0	6.993
5.8	0.735	10.0	1.680	13.1	2.855	14.4	3.986	16.5	5.363	19.0	7.057
6.1	0.765	10.4	1.701	13.2	2.883	14.1	4.013	16.5	5.413	18.8	7.094
5.7	0.783	10.4	1.727	13.2	2.911	14.2	4.056	16.3	5.436	18.3	7.121
6.1	0.807	10.2	1.756	13.3	2.944	14.4	4.084	16.3	5.480	18.7	7.172
6.3	0.835	10.6	1.793	13.1	2.969	14.4	4.120	16.4	5.521	19.0	7.245
6.6	0.864	10.9	1.819	13.5	3.004	14.7	4.157	16.5	5.571	19.0	7.293
6.7	0.885	11.2	1.859	13.7	3.040	14.9	4.196	17.2	5.618	19.2	7.349

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
18.8	7.384	22.5	9.841	28.6	13.492	31.6	17.552	36.6	22.941	4.5	32.094
19.7	7.465	23.0	9.891	29.8	13.596	34.1	17.721	33.6	23.087	4.5	32.427
19.9	7.519	23.3	9.968	30.9	13.720	32.5	17.815	35.9	23.269		
20.1	7.579	24.0	10.059	29.4	13.792	33.8	17.945	32.5	23.357		
19.2	7.614	23.2	10.116	30.2	13.887	32.1	18.033	36.2	23.598		
20.0	7.685	23.6	10.175	30.0	13.991	33.5	18.165	36.6	23.797		
20.3	7.740	24.3	10.271	28.9	14.050	32.8	18.289	34.1	23.908		
20.4	7.800	24.2	10.339	30.9	14.201	33.0	18.377	35.9	24.117		
20.5	7.852	24.2	10.411	30.0	14.269	33.5	18.514	32.6	24.218		
20.8	7.928	25.0	10.491	29.6	14.346	31.0	18.568	34.7	24.490		
21.4	8.001	25.0	10.573	31.8	14.507	33.0	18.728	33.4	24.572		
21.9	8.080	23.6	10.616	30.1	14.591	32.1	18.806	34.5	24.787		
20.7	8.116	25.9	10.741	31.9	14.717	31.2	18.876	36.4	25.009		
21.3	8.195	26.1	10.831	31.0	14.811	33.4	19.038	36.0	25.241		
21.5	8.255	24.9	10.881	30.6	14.894	30.5	19.114	34.7	25.392		
21.9	8.323	26.4	10.999	31.9	15.051	33.7	19.268	36.4	25.628		
20.9	8.363	26.7	11.113	29.9	15.091	31.8	19.365	34.5	25.796		
21.0	8.419	26.3	11.171	30.1	15.179	32.2	19.478	32.8	26.018		
21.0	8.464	27.6	11.284	30.2	15.279	32.4	19.626	35.8	26.295		
21.3	8.523	26.9	11.365	29.1	15.348	32.5	19.708	37.2	26.561		
21.0	8.574	26.2	11.435	28.6	15.406	34.4	19.895	34.9	26.747		
20.0	8.612	28.2	11.548	29.5	15.502	34.8	20.025	33.5	27.021		
20.8	8.663	27.4	11.643	29.1	15.579	33.7	20.192	33.0	27.240		
21.5	8.733	27.5	11.727	27.7	15.638	35.0	20.318	34.6	27.533		
21.3	8.789	28.9	11.879	29.0	15.727	34.6	20.472	33.9	27.757		
20.7	8.839	27.0	11.920	29.8	15.846	35.9	20.633	31.9	28.031		
19.7	8.861	28.5	12.039	29.4	15.912	33.8	20.768	29.2	28.212		
21.2	8.932	29.1	12.148	30.8	16.060	34.5	20.890	29.6	28.526		
21.7	9.005	27.6	12.210	29.4	16.123	34.3	21.017	29.7	28.834		
22.1	9.089	29.2	12.324	30.3	16.220	31.5	21.090	28.6	29.177		
21.7	9.132	29.2	12.428	31.2	16.343	34.3	21.301	26.2	29.398		
22.2	9.198	30.2	12.539	28.8	16.409	33.1	21.377	20.6	29.588		
22.7	9.277	30.1	12.685	30.7	16.520	35.7	21.574	20.3	29.895		
21.8	9.337	28.7	12.736	31.2	16.635	33.2	21.666	18.8	30.226		
21.8	9.371	30.7	12.873	30.3	16.707	34.9	21.875	15.0	30.344		
22.0	9.439	29.9	12.964	31.8	16.862	33.4	21.954	13.6	30.638		
22.5	9.517	29.4	13.057	30.1	16.923	35.0	22.143	13.4	30.969		
22.4	9.588	30.3	13.158	31.8	17.061	33.6	22.247	11.3	31.212		
22.4	9.624	28.7	13.226	31.8	17.181	34.4	22.452	8.6	31.372		
22.4	9.692	28.9	13.310	32.9	17.316	34.7	22.585	8.9	31.674		
23.3	9.776	30.4	13.450	33.3	17.474	34.4	22.744	6.7	31.832		

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Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
0.0	0.000	6.0	1.195	10.5	2.310	11.8	3.150	13.1	3.970	13.6	4.620
0.3	0.020	6.3	1.225	10.6	2.345	12.1	3.170	13.2	3.980	13.8	4.630
0.0	0.065	6.4	1.275	10.5	2.390	11.9	3.190	13.3	4.005	13.8	4.650
0.4	0.100	6.3	1.295	10.9	2.415	12.1	3.205	13.2	4.020	13.7	4.665
0.8	0.135	6.4	1.325	10.8	2.450	11.9	3.220	13.2	4.040	13.6	4.685
0.2	0.155	6.4	1.350	10.6	2.465	11.9	3.240	13.2	4.055	14.1	4.705
0.5	0.190	7.0	1.395	10.7	2.495	12.1	3.260	13.4	4.080	13.9	4.730
0.6	0.215	7.1	1.430	10.7	2.515	12.0	3.275	13.4	4.095	14.0	4.745
1.3	0.255	7.2	1.470	11.0	2.535	12.3	3.305	13.6	4.115	13.6	4.765
0.8	0.275	7.7	1.495	10.6	2.550	12.0	3.325	13.4	4.135	14.0	4.785
1.1	0.310	7.8	1.535	10.8	2.570	12.0	3.345	13.6	4.150	13.7	4.805
1.0	0.335	7.6	1.555	10.8	2.590	12.1	3.365	13.3	4.170	14.3	4.820
1.5	0.380	7.9	1.585	10.9	2.615	12.1	3.385	13.2	4.190	14.2	4.835
1.3	0.405	7.8	1.615	10.8	2.635	12.4	3.400	13.2	4.200	13.8	4.855
1.2	0.430	8.3	1.650	11.1	2.665	12.1	3.425	13.5	4.225	14.3	4.875
1.5	0.450	8.2	1.675	11.2	2.685	12.1	3.435	13.7	4.245	14.2	4.890
1.6	0.475	8.4	1.715	10.9	2.705	12.3	3.460	13.3	4.270	14.5	4.915
1.9	0.500	8.7	1.740	10.9	2.725	12.6	3.480	13.5	4.285	14.1	4.935
1.9	0.535	8.7	1.780	11.0	2.745	12.4	3.500	13.3	4.305	14.2	4.955
2.2	0.565	8.8	1.800	11.0	2.755	12.3	3.510	13.7	4.320	14.5	4.975
2.3	0.590	8.8	1.840	10.9	2.775	12.7	3.550	13.6	4.335	14.2	5.005
2.1	0.615	8.9	1.860	10.9	2.785	13.0	3.575	13.1	4.350	14.8	5.025
2.5	0.650	8.9	1.895	11.0	2.805	13.3	3.620	13.4	4.365	14.5	5.055
3.0	0.690	9.2	1.920	11.0	2.825	13.2	3.640	13.2	4.375	14.7	5.075
3.0	0.725	9.5	1.960	11.0	2.855	13.0	3.670	13.4	4.395	14.8	5.095
3.4	0.760	9.2	1.980	11.6	2.875	13.0	3.690	13.2	4.405	14.8	5.115
3.7	0.810	9.4	2.010	11.7	2.900	13.3	3.715	13.5	4.420	14.9	5.145
3.7	0.830	9.1	2.030	11.4	2.925	13.4	3.735	13.2	4.430	15.0	5.165
4.0	0.880	9.3	2.050	11.7	2.950	13.2	3.760	13.2	4.450	14.9	5.190
4.0	0.900	9.1	2.060	11.4	2.965	13.0	3.780	13.4	4.460	15.0	5.205
4.3	0.930	9.6	2.090	11.8	2.985	13.1	3.805	13.4	4.480	14.4	5.225
4.4	0.950	9.7	2.115	11.3	3.000	13.2	3.825	13.2	4.490	15.0	5.245
4.7	0.990	9.8	2.150	11.5	3.020	13.2	3.850	13.5	4.510	14.8	5.265
4.6	1.015	9.7	2.170	11.5	3.030	13.4	3.870	13.1	4.525	15.1	5.285
5.3	1.060	9.8	2.205	11.6	3.060	13.3	3.890	13.4	4.540	14.5	5.300
5.3	1.095	10.1	2.225	11.7	3.080	13.2	3.905	13.5	4.560	15.0	5.320
5.5	1.125	9.9	2.255	11.4	3.100	13.0	3.930	13.4	4.580	14.9	5.345
5.6	1.155	10.2	2.275	11.7	3.120	12.9	3.945	13.7	4.595	14.6	5.360

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
14.8	5.385	15.7	6.115	17.5	7.090	18.9	8.035	21.8	9.330	23.1	10.620
15.2	5.400	15.9	6.145	17.3	7.110	18.5	8.055	22.0	9.360	23.5	10.670
15.0	5.415	15.6	6.155	17.5	7.140	18.8	8.075	22.3	9.410	23.9	10.690
14.9	5.430	16.1	6.195	17.7	7.160	18.9	8.105	22.8	9.440	23.3	10.730
14.6	5.445	16.1	6.215	17.8	7.190	18.6	8.125	22.3	9.480	24.2	10.770
14.7	5.455	16.3	6.255	17.5	7.210	19.0	8.165	22.1	9.500	23.9	10.810
14.5	5.470	16.5	6.275	17.8	7.230	19.4	8.185	22.8	9.560	24.1	10.840
14.4	5.480	16.2	6.295	17.8	7.250	19.8	8.230	23.0	9.585	24.2	10.880
14.3	5.495	16.5	6.315	17.4	7.270	19.7	8.260	22.7	9.625	24.0	10.915
14.5	5.510	16.4	6.345	17.7	7.280	20.4	8.305	22.9	9.650	24.6	10.960
14.6	5.525	16.3	6.365	17.6	7.300	19.8	8.325	22.2	9.680	24.4	10.995
14.7	5.545	15.9	6.380	17.4	7.310	19.6	8.345	22.3	9.700	24.5	11.025
15.0	5.570	16.8	6.405	17.0	7.320	19.5	8.370	22.1	9.730	24.0	11.050
14.5	5.585	16.7	6.435	16.8	7.335	19.7	8.400	22.4	9.760	24.6	11.100
14.7	5.615	17.1	6.465	17.1	7.355	19.9	8.420	22.8	9.800	25.2	11.150
15.0	5.630	16.9	6.505	17.6	7.380	20.1	8.450	22.4	9.840	25.5	11.205
15.1	5.650	17.3	6.530	17.3	7.405	19.7	8.480	23.0	9.880	25.6	11.240
14.7	5.665	17.1	6.560	17.3	7.425	20.5	8.520	22.9	9.905	25.2	11.280
15.1	5.685	17.1	6.585	17.7	7.450	20.7	8.560	22.1	9.930	25.5	11.325
14.9	5.700	16.6	6.605	17.1	7.465	20.6	8.585	22.6	9.950	26.1	11.385
15.0	5.720	17.3	6.635	18.1	7.505	20.7	8.620	22.5	9.980	25.7	11.415
14.9	5.730	17.3	6.675	18.4	7.535	20.8	8.660	22.3	10.010	25.6	11.465
15.1	5.760	17.4	6.695	18.5	7.575	21.0	8.690	23.0	10.050	25.2	11.485
15.4	5.780	17.6	6.730	18.4	7.595	20.9	8.730	22.7	10.070	25.5	11.535
15.3	5.800	17.6	6.755	18.9	7.635	21.1	8.750	22.9	10.110	25.7	11.575
15.6	5.820	17.3	6.785	18.7	7.655	20.7	8.780	22.7	10.135	25.8	11.625
15.4	5.840	17.5	6.805	18.4	7.675	20.2	8.790	22.1	10.160	25.6	11.650
15.3	5.850	17.2	6.825	18.4	7.690	20.9	8.830	22.8	10.190	25.2	11.685
15.5	5.875	17.1	6.840	18.9	7.725	20.7	8.860	22.7	10.220	25.2	11.705
15.5	5.890	17.1	6.865	18.6	7.750	20.7	8.890	22.7	10.240	25.4	11.755
15.5	5.910	17.4	6.880	19.1	7.790	20.7	8.920	23.1	10.290	25.9	11.790
15.8	5.925	17.1	6.900	19.2	7.820	21.1	8.965	23.1	10.320	25.6	11.845
15.1	5.940	17.2	6.920	18.6	7.845	21.5	8.995	23.2	10.360	26.1	11.880
15.0	5.950	17.4	6.950	18.8	7.865	20.7	9.020	23.1	10.380	25.9	11.925
15.4	5.980	17.3	6.965	18.7	7.885	21.4	9.050	22.9	10.410	25.2	11.940
15.5	5.990	16.8	6.980	18.6	7.900	21.9	9.105	23.2	10.440	25.6	11.990
15.4	6.010	17.2	6.990	18.8	7.920	22.5	9.155	23.2	10.475	25.6	12.020
15.2	6.030	16.6	7.000	18.5	7.945	22.9	9.215	23.0	10.500	25.3	12.060
15.3	6.055	16.8	7.020	18.7	7.970	22.4	9.245	23.1	10.535	25.5	12.090
15.4	6.070	17.2	7.040	18.6	7.995	21.7	9.270	23.1	10.560	25.6	12.135
15.8	6.100	17.1	7.060	18.5	8.015	21.8	9.295	22.8	10.590	25.6	12.150

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
25.8	12.210	29.5	14.115	35.3	16.555	36.6	19.365	44.4	23.605	49.9	29.670
26.3	12.260	29.9	14.180	35.2	16.625	37.3	19.475	44.9	23.745	50.7	29.930
26.4	12.310	29.9	14.230	34.2	16.680	37.8	19.555	42.5	23.820	46.2	30.025
26.7	12.350	28.9	14.260	34.1	16.730	36.9	19.625	44.5	23.960	47.2	30.310
25.6	12.385	29.4	14.300	34.9	16.830	37.6	19.695	42.5	24.050	51.3	30.575
26.4	12.425	29.1	14.350	34.7	16.880	37.3	19.785	44.1	24.175	50.9	30.825
26.8	12.485	29.1	14.390	33.8	16.935	36.4	19.825	43.7	24.315	46.0	30.940
27.2	12.525	29.3	14.460	34.3	16.995	37.3	19.925	44.2	24.420	47.0	31.215
26.7	12.575	28.9	14.485	35.0	17.095	38.5	20.015	44.4	24.585	50.2	31.475
26.9	12.610	29.2	14.540	34.2	17.130	36.7	20.090	45.0	24.700	50.3	31.745
26.7	12.645	29.3	14.580	35.3	17.245	39.8	20.225	44.8	24.865	45.4	31.850
27.1	12.690	29.8	14.640	35.8	17.315	38.9	20.335	45.9	24.990	45.8	32.130
27.7	12.765	29.9	14.685	34.9	17.385	38.3	20.380	45.0	25.145	49.1	32.405
27.6	12.805	29.5	14.730	35.1	17.445	39.2	20.495	44.1	25.225	49.4	32.705
27.2	12.845	30.0	14.775	35.6	17.535	39.6	20.585	45.6	25.400	45.0	32.820
27.3	12.875	29.9	14.850	35.9	17.600	38.6	20.665	43.5	25.460	43.6	33.090
27.7	12.935	30.4	14.900	34.8	17.650	40.3	20.785	46.0	25.665	46.2	33.355
28.3	12.985	29.9	14.950	35.3	17.725	38.9	20.865	42.8	25.715	46.5	33.645
28.0	13.045	30.4	15.000	35.4	17.800	39.5	20.950	46.9	25.935	43.7	33.775
27.9	13.080	31.6	15.090	35.0	17.850	40.6	21.075	43.5	25.995	41.1	34.025
27.3	13.115	32.2	15.160	34.0	17.890	38.8	21.115	46.3	26.235	44.0	34.295
27.6	13.150	31.5	15.215	34.0	17.935	41.9	21.280	47.0	26.365	44.6	34.580
27.1	13.190	31.6	15.275	34.1	18.000	40.8	21.365	45.9	26.535	40.8	34.710
27.4	13.230	32.1	15.360	34.5	18.060	41.4	21.470	45.9	26.645	39.3	34.990
27.7	13.280	32.0	15.410	33.7	18.120	42.5	21.590	45.5	26.815	41.0	35.255
27.7	13.310	31.4	15.455	34.2	18.180	42.0	21.685	46.6	26.950	41.0	35.565
27.2	13.350	31.7	15.520	34.3	18.255	43.6	21.850	45.2	27.115	39.5	35.730
27.5	13.390	32.9	15.625	34.7	18.320	41.5	21.940	49.0	27.325	35.6	35.945
28.1	13.455	32.3	15.670	34.7	18.380	43.6	22.080	45.2	27.440	37.6	36.230
28.6	13.510	31.9	15.725	35.5	18.460	41.6	22.155	47.3	27.610	37.6	36.545
28.1	13.545	31.9	15.775	36.0	18.570	42.5	22.255	43.9	27.715	39.3	36.820
28.4	13.595	31.8	15.835	34.5	18.600	42.8	22.390	47.9	27.920	37.3	37.110
28.6	13.665	31.7	15.885	35.3	18.700	42.4	22.460	45.8	28.050	32.3	37.250
29.0	13.705	31.1	15.925	36.1	18.775	44.0	22.665	47.4	28.225	31.6	37.575
29.3	13.770	33.1	16.005	35.3	18.840	41.9	22.720	46.8	28.390	33.6	37.870
29.0	13.805	33.2	16.105	35.2	18.880	44.9	22.910	46.2	28.530	32.3	38.195
29.5	13.875	32.7	16.150	35.9	18.970	42.7	22.965	47.1	28.720	30.3	38.405
29.1	13.915	33.6	16.235	36.2	19.055	44.1	23.130	45.0	28.825	28.2	38.735
29.6	13.975	34.0	16.305	35.3	19.115	44.0	23.230	48.2	29.075	25.3	38.960
28.9	14.010	34.1	16.390	36.5	19.195	44.0	23.355	45.5	29.175	23.9	39.305
29.2	14.065	33.6	16.435	37.6	19.325	44.9	23.490	45.7	29.425	24.5	39.625

Wallette 16

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
0.0	0.000	2.4	0.350	5.0	0.755	6.4	1.235	7.8	1.780	8.1	2.205
0.1	0.005	2.6	0.355	5.1	0.775	6.7	1.250	7.8	1.795	8.3	2.220
0.4	0.030	2.6	0.365	4.9	0.785	6.8	1.265	7.6	1.805	8.3	2.230
0.4	0.035	2.7	0.380	4.8	0.795	6.5	1.280	7.9	1.815	8.6	2.240
0.4	0.045	2.7	0.380	5.1	0.805	6.9	1.290	7.7	1.825	8.4	2.250
0.6	0.060	2.8	0.390	5.1	0.825	6.9	1.300	7.8	1.840	8.4	2.265
0.2	0.070	2.7	0.400	5.7	0.835	6.6	1.315	7.9	1.845	8.6	2.280
0.4	0.080	3.1	0.410	5.2	0.845	6.6	1.330	8.0	1.865	8.4	2.290
0.7	0.085	2.6	0.420	5.3	0.855	6.9	1.350	7.8	1.865	8.7	2.300
0.5	0.100	2.6	0.430	5.4	0.865	7.0	1.365	7.8	1.880	8.4	2.315
0.7	0.105	3.0	0.435	5.5	0.875	7.1	1.380	7.7	1.885	8.8	2.325
0.6	0.120	3.2	0.450	5.4	0.885	7.3	1.400	7.9	1.900	8.5	2.335
0.8	0.130	3.1	0.450	5.4	0.895	7.1	1.410	7.6	1.905	8.7	2.345
0.8	0.140	2.9	0.460	5.2	0.905	7.3	1.425	7.8	1.920	8.6	2.355
1.1	0.150	3.2	0.470	5.5	0.915	7.2	1.435	7.9	1.930	8.5	2.365
0.7	0.155	3.3	0.480	5.6	0.930	7.0	1.450	7.8	1.940	8.7	2.380
1.2	0.165	3.2	0.490	5.5	0.935	7.2	1.460	7.9	1.950	9.0	2.390
0.9	0.175	3.5	0.500	5.5	0.950	7.2	1.475	7.8	1.960	8.8	2.410
1.3	0.175	3.2	0.500	5.5	0.960	6.9	1.485	7.9	1.970	9.1	2.425
1.2	0.185	3.4	0.515	5.7	0.970	6.8	1.500	7.9	1.980	8.6	2.435
1.3	0.195	3.5	0.520	5.9	0.980	7.3	1.510	7.8	1.990	8.7	2.445
1.2	0.200	3.4	0.530	5.7	0.995	7.4	1.525	7.8	2.000	9.1	2.465
1.0	0.210	3.5	0.540	5.9	1.005	7.2	1.535	7.8	2.015	9.2	2.475
1.4	0.220	3.4	0.550	5.9	1.015	7.3	1.545	8.1	2.025	8.9	2.485
1.5	0.225	3.8	0.560	6.0	1.025	7.2	1.555	7.9	2.040	8.8	2.500
1.3	0.230	3.8	0.580	5.7	1.040	7.1	1.570	8.2	2.055	9.2	2.510
1.6	0.240	3.9	0.590	5.9	1.050	7.2	1.585	8.1	2.065	9.1	2.520
1.4	0.245	4.3	0.605	5.9	1.060	7.6	1.605	8.0	2.075	9.3	2.535
1.7	0.250	4.0	0.620	5.6	1.075	7.8	1.615	8.0	2.085	9.0	2.545
2.1	0.260	4.1	0.630	6.2	1.085	7.6	1.635	8.0	2.100	9.1	2.555
2.1	0.270	4.2	0.640	6.3	1.095	7.7	1.650	8.4	2.105	9.0	2.565
1.8	0.275	4.4	0.660	6.0	1.115	7.6	1.665	8.2	2.115	8.8	2.580
1.8	0.280	4.8	0.670	6.1	1.125	7.6	1.675	8.2	2.125	9.2	2.585
2.0	0.290	4.6	0.680	6.2	1.140	7.8	1.690	8.3	2.135	8.6	2.600
2.2	0.295	4.5	0.690	6.2	1.150	7.8	1.710	8.0	2.145	9.4	2.610
2.2	0.305	4.3	0.700	6.2	1.165	7.5	1.720	8.2	2.155	9.0	2.625
2.2	0.315	4.8	0.710	6.3	1.180	7.5	1.730	8.1	2.165	9.2	2.635
2.0	0.320	4.7	0.720	6.4	1.195	7.6	1.745	8.2	2.175	9.4	2.645
2.5	0.330	4.7	0.730	6.8	1.205	7.6	1.755	8.2	2.185	8.9	2.655
2.4	0.340	4.7	0.745	6.8	1.220	7.8	1.770	8.2	2.195	9.2	2.670

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
9.6	2.675	9.7	3.045	10.4	3.475	11.3	3.875	11.4	4.245	12.0	4.610
9.2	2.695	9.5	3.060	10.7	3.490	11.2	3.885	11.6	4.255	11.9	4.620
9.1	2.695	9.9	3.070	10.2	3.495	11.1	3.895	11.5	4.260	11.8	4.625
9.2	2.710	9.7	3.080	10.6	3.505	11.1	3.905	11.5	4.270	11.9	4.630
9.3	2.715	9.7	3.090	10.1	3.510	11.1	3.915	11.4	4.275	12.1	4.640
9.5	2.725	9.5	3.105	10.4	3.520	10.9	3.915	11.8	4.290	11.9	4.650
9.2	2.735	9.8	3.115	10.2	3.530	11.2	3.930	11.3	4.295	12.2	4.660
9.3	2.745	9.8	3.125	10.5	3.540	11.2	3.940	11.6	4.305	12.0	4.670
9.3	2.755	9.8	3.135	10.4	3.545	11.1	3.945	11.5	4.310	11.9	4.675
9.3	2.765	9.9	3.150	10.6	3.560	11.1	3.955	11.9	4.325	12.1	4.690
9.0	2.765	9.7	3.155	10.2	3.570	11.0	3.965	11.5	4.330	12.2	4.700
9.2	2.775	10.0	3.170	10.5	3.580	11.0	3.975	12.1	4.340	12.3	4.710
9.3	2.785	10.3	3.180	10.4	3.580	11.3	3.985	11.5	4.350	12.4	4.720
9.0	2.795	9.7	3.190	10.7	3.600	11.1	3.990	11.7	4.360	12.4	4.730
9.3	2.805	10.0	3.200	10.7	3.605	11.1	3.995	11.7	4.370	12.4	4.740
9.3	2.815	9.9	3.210	10.7	3.620	11.1	4.010	11.5	4.380	12.4	4.755
9.2	2.820	10.0	3.210	10.8	3.625	10.9	4.020	11.8	4.380	12.2	4.760
9.3	2.835	10.1	3.230	10.7	3.640	11.4	4.030	11.5	4.390	12.2	4.770
9.2	2.840	9.9	3.240	10.7	3.650	11.1	4.035	11.5	4.400	12.3	4.775
9.1	2.850	10.1	3.250	10.6	3.660	11.4	4.045	11.8	4.410	12.1	4.785
9.4	2.855	10.1	3.260	10.7	3.670	10.9	4.055	11.8	4.420	12.1	4.790
9.1	2.865	9.9	3.270	10.8	3.680	11.4	4.065	11.4	4.425	12.0	4.795
9.1	2.875	9.9	3.280	10.8	3.685	11.3	4.075	11.8	4.430	12.2	4.805
9.2	2.885	10.1	3.290	10.5	3.700	11.1	4.085	11.7	4.440	12.3	4.825
9.2	2.895	10.3	3.300	10.7	3.705	11.1	4.095	11.5	4.450	12.2	4.825
9.5	2.905	10.3	3.320	10.7	3.715	11.6	4.105	11.6	4.460	12.3	4.835
9.2	2.915	10.5	3.330	10.5	3.720	11.4	4.115	11.8	4.470	12.2	4.845
9.5	2.925	10.3	3.340	10.6	3.725	11.5	4.125	11.8	4.480	12.3	4.855
9.2	2.935	10.1	3.350	10.5	3.730	11.9	4.135	11.8	4.490	12.5	4.865
9.3	2.950	10.6	3.360	11.0	3.755	11.0	4.145	11.9	4.505	12.2	4.875
9.6	2.955	10.4	3.370	11.0	3.765	11.9	4.155	12.1	4.515	12.3	4.885
9.4	2.965	10.5	3.385	11.1	3.780	11.2	4.165	12.2	4.530	12.5	4.895
9.5	2.975	10.4	3.395	11.1	3.785	11.7	4.175	12.2	4.540	12.3	4.900
9.7	2.985	10.5	3.405	11.0	3.800	11.3	4.185	12.0	4.550	12.3	4.910
9.5	2.995	10.6	3.415	11.2	3.810	11.2	4.195	11.9	4.560	12.4	4.915
9.6	3.005	10.7	3.430	11.1	3.825	11.5	4.205	12.1	4.570	12.7	4.930
9.7	3.010	10.5	3.435	11.1	3.835	11.3	4.210	12.0	4.575	12.3	4.935
9.4	3.020	10.7	3.450	10.9	3.845	11.2	4.220	12.0	4.585	12.3	4.945
9.5	3.030	10.6	3.460	11.0	3.855	11.6	4.225	12.2	4.595	12.4	4.950
9.5	3.040	10.7	3.470	11.1	3.865	11.6	4.240	12.1	4.600	13.0	4.960

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
12.2	4.965	12.9	5.295	13.3	5.685	13.3	6.000	13.7	6.325	15.1	6.750
12.1	4.970	12.7	5.305	13.3	5.695	14.1	6.020	13.6	6.335	15.4	6.750
12.3	4.980	12.8	5.315	13.0	5.695	13.9	6.030	13.6	6.345	14.9	6.760
12.1	4.985	12.7	5.325	13.3	5.705	13.8	6.040	13.7	6.355	15.2	6.770
12.2	4.990	12.9	5.335	13.1	5.715	13.6	6.050	13.9	6.365	14.8	6.770
12.2	5.000	12.9	5.350	13.9	5.725	13.7	6.060	14.1	6.375	14.7	6.780
12.0	5.005	12.9	5.360	13.0	5.730	13.8	6.065	14.0	6.385	14.7	6.785
12.3	5.015	13.4	5.375	13.3	5.740	14.2	6.075	14.0	6.395	14.6	6.790
12.4	5.025	13.2	5.385	13.2	5.745	13.5	6.085	14.2	6.405	14.8	6.800
12.6	5.035	13.3	5.395	13.1	5.755	14.1	6.095	14.3	6.415	14.9	6.810
12.1	5.035	13.5	5.405	13.1	5.760	13.9	6.105	14.6	6.425	14.9	6.820
12.4	5.045	13.5	5.425	13.2	5.770	13.6	6.110	14.2	6.435	14.9	6.830
12.4	5.055	13.1	5.430	13.0	5.775	13.7	6.115	14.6	6.445	15.2	6.840
12.4	5.065	13.0	5.440	13.0	5.785	13.7	6.125	14.3	6.455	14.9	6.850
12.3	5.070	13.3	5.450	13.6	5.795	13.6	6.125	14.4	6.465	15.2	6.860
12.7	5.080	13.3	5.455	13.5	5.805	13.6	6.135	14.4	6.475	15.1	6.870
12.6	5.085	13.0	5.465	13.1	5.810	13.6	6.145	14.4	6.490	15.1	6.870
12.5	5.095	12.7	5.475	13.6	5.820	13.7	6.155	14.6	6.505	14.9	6.880
12.6	5.105	13.1	5.480	13.1	5.830	13.9	6.165	14.9	6.515	14.7	6.890
12.3	5.115	13.4	5.500	13.3	5.840	14.0	6.175	15.1	6.530	14.7	6.895
12.3	5.120	13.3	5.510	13.3	5.850	13.6	6.185	14.8	6.540	15.0	6.900
12.5	5.130	13.5	5.520	13.6	5.855	13.7	6.190	14.8	6.550	14.9	6.910
12.2	5.135	13.0	5.530	13.6	5.865	13.6	6.195	14.9	6.560	15.0	6.910
12.4	5.145	13.1	5.540	13.7	5.875	13.9	6.205	14.9	6.575	14.7	6.920
12.6	5.155	12.9	5.550	13.6	5.880	13.6	6.215	14.6	6.580	14.6	6.920
12.4	5.160	13.2	5.560	13.5	5.890	14.0	6.215	14.7	6.590	14.9	6.930
12.4	5.165	13.2	5.570	13.3	5.895	13.5	6.225	14.8	6.595	14.7	6.940
12.3	5.175	12.9	5.580	13.2	5.905	13.5	6.235	14.8	6.600	14.9	6.955
12.1	5.185	13.3	5.585	13.2	5.910	13.7	6.240	14.7	6.610	15.0	6.970
12.8	5.200	13.4	5.595	13.8	5.920	13.7	6.245	14.6	6.615	15.1	6.980
12.2	5.205	13.2	5.605	13.2	5.925	13.5	6.255	14.5	6.620	15.4	6.990
12.3	5.215	13.1	5.610	13.3	5.930	13.5	6.265	14.3	6.630	15.2	7.000
12.5	5.220	13.1	5.620	13.3	5.935	13.9	6.270	15.0	6.640	14.9	7.005
12.6	5.235	13.3	5.630	13.2	5.945	13.9	6.275	14.8	6.660	15.3	7.015
12.6	5.240	13.0	5.630	13.0	5.950	13.8	6.285	14.9	6.670	15.2	7.025
12.6	5.250	13.1	5.640	13.5	5.960	13.6	6.295	15.1	6.690	15.8	7.035
12.7	5.260	12.9	5.650	13.4	5.970	13.7	6.300	15.3	6.700	15.3	7.045
12.8	5.270	13.0	5.655	13.1	5.970	14.1	6.310	17.5	6.710	15.2	7.055
12.6	5.280	13.1	5.665	13.5	5.985	13.5	6.315	15.5	6.720	15.6	7.065
12.6	5.290	12.9	5.675	13.5	5.995	13.7	6.325	15.2	6.740	15.6	7.075

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
15.5	7.085	15.8	7.435	16.3	7.790	16.8	8.130	18.0	8.580	18.3	9.075
15.4	7.090	16.1	7.455	16.4	7.805	16.3	8.140	18.4	8.600	18.6	9.085
15.3	7.095	16.4	7.465	16.5	7.805	16.3	8.145	18.5	8.615	18.5	9.095
15.6	7.100	16.4	7.475	16.4	7.820	16.3	8.155	18.4	8.625	18.0	9.110
15.5	7.115	16.2	7.485	16.3	7.825	16.3	8.160	18.1	8.635	18.5	9.120
15.4	7.125	16.2	7.505	16.0	7.835	16.1	8.165	17.9	8.645	18.3	9.130
15.3	7.130	16.1	7.515	16.2	7.845	16.5	8.180	18.3	8.655	18.2	9.140
15.1	7.135	16.3	7.525	16.2	7.855	16.7	8.190	18.2	8.665	17.9	9.145
15.3	7.145	16.5	7.535	16.3	7.855	16.8	8.200	18.1	8.680	18.3	9.150
15.3	7.155	16.3	7.545	15.9	7.865	16.7	8.210	18.1	8.695	18.3	9.160
15.2	7.155	16.1	7.550	16.1	7.875	16.8	8.220	18.4	8.705	18.3	9.180
15.4	7.175	16.2	7.560	16.4	7.885	16.8	8.240	18.7	8.720	18.4	9.190
15.3	7.185	16.2	7.565	16.1	7.895	16.9	8.250	18.6	8.735	18.3	9.200
15.5	7.195	16.0	7.575	16.4	7.905	17.0	8.255	18.4	8.750	18.5	9.210
15.4	7.200	16.0	7.575	16.1	7.915	16.8	8.260	18.6	8.755	18.5	9.220
15.4	7.215	16.3	7.595	16.4	7.920	16.6	8.270	18.8	8.775	18.3	9.230
15.6	7.220	16.3	7.605	16.3	7.925	16.9	8.280	18.8	8.785	18.6	9.245
15.4	7.230	16.4	7.615	16.3	7.940	16.9	8.290	18.4	8.800	18.6	9.255
15.6	7.235	16.5	7.625	16.1	7.950	17.0	8.295	18.6	8.810	18.8	9.265
15.3	7.245	16.2	7.635	16.4	7.960	16.8	8.300	18.5	8.820	18.9	9.275
15.4	7.245	16.3	7.645	16.1	7.965	17.0	8.310	18.6	8.825	18.8	9.285
15.0	7.255	16.5	7.655	16.0	7.975	17.0	8.320	18.6	8.835	18.6	9.295
15.1	7.265	16.5	7.660	16.2	7.985	17.4	8.340	18.5	8.850	18.9	9.305
15.3	7.275	16.2	7.665	15.9	7.985	17.4	8.350	18.5	8.865	18.6	9.315
15.7	7.285	16.0	7.675	16.0	7.995	17.7	8.360	18.7	8.875	18.9	9.325
15.6	7.295	16.2	7.675	16.0	8.005	17.2	8.380	18.4	8.900	18.8	9.345
15.5	7.300	16.0	7.685	15.9	8.005	17.7	8.390	18.2	8.915	19.3	9.355
15.5	7.310	16.0	7.690	15.7	8.015	17.5	8.405	18.7	8.940	19.3	9.375
15.8	7.320	15.8	7.695	15.8	8.015	17.2	8.410	18.5	8.945	19.4	9.380
15.6	7.335	15.8	7.700	16.3	8.035	17.5	8.430	18.4	8.955	19.1	9.400
15.9	7.340	15.9	7.705	16.0	8.045	17.6	8.440	17.9	8.965	19.5	9.410
15.8	7.350	15.7	7.705	16.2	8.055	17.8	8.450	18.0	8.985	19.8	9.420
15.7	7.360	15.6	7.715	16.2	8.065	17.3	8.460	18.0	8.990	19.8	9.435
15.5	7.375	15.6	7.725	16.3	8.075	17.8	8.475	17.8	9.000	19.4	9.450
15.9	7.380	16.0	7.735	16.5	8.080	17.5	8.480	18.2	9.000	19.7	9.460
16.0	7.390	16.0	7.745	16.4	8.090	17.9	8.500	17.9	9.020	19.3	9.470
15.8	7.400	16.1	7.755	16.6	8.095	17.9	8.510	18.3	9.030	19.5	9.480
15.7	7.410	16.1	7.765	16.2	8.105	17.9	8.530	18.0	9.045	19.5	9.490
15.7	7.410	16.1	7.770	16.5	8.115	18.1	8.540	18.2	9.055	19.7	9.500
15.8	7.425	16.1	7.780	16.2	8.125	18.5	8.560	17.9	9.065	19.6	9.515

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
19.8	9.525	21.0	10.030	20.4	10.425	21.6	10.880	21.8	11.310	23.0	11.800
19.9	9.545	21.0	10.045	20.8	10.445	21.5	10.895	22.2	11.330	23.1	11.815
20.2	9.555	21.1	10.055	21.4	10.470	21.4	10.905	22.0	11.345	23.3	11.820
20.4	9.585	21.1	10.065	21.9	10.500	21.6	10.925	22.4	11.355	23.2	11.835
20.3	9.600	21.0	10.075	22.2	10.525	22.0	10.940	22.1	11.370	23.7	11.855
20.3	9.620	21.0	10.095	22.4	10.545	21.9	10.955	22.8	11.385	24.1	11.875
20.3	9.630	20.9	10.105	22.2	10.555	21.9	10.960	22.5	11.395	24.1	11.890
20.4	9.640	20.6	10.115	22.0	10.575	21.6	10.975	22.5	11.405	23.8	11.905
20.2	9.650	20.3	10.115	22.0	10.585	21.8	10.980	22.2	11.415	23.6	11.915
20.5	9.660	21.3	10.135	21.6	10.590	21.5	10.990	22.5	11.425	23.8	11.930
20.2	9.670	21.3	10.145	21.8	10.600	21.6	11.000	22.3	11.430	23.8	11.940
20.2	9.680	21.1	10.155	21.6	10.610	21.4	11.005	22.1	11.440	23.9	11.960
20.2	9.690	20.9	10.175	21.6	10.615	21.3	11.010	21.8	11.445	24.1	11.970
20.2	9.700	21.6	10.195	21.3	10.625	21.4	11.025	21.6	11.450	24.1	11.990
19.9	9.710	21.5	10.205	21.7	10.635	21.6	11.035	22.3	11.465	24.3	12.000
20.6	9.730	21.8	10.215	21.3	10.645	21.6	11.050	22.6	11.475	24.3	12.020
20.3	9.740	21.1	10.230	21.7	10.660	21.6	11.060	22.4	11.485	24.7	12.040
20.2	9.750	21.2	10.240	21.6	10.675	22.0	11.075	22.5	11.505	24.7	12.060
20.2	9.760	21.4	10.245	21.9	10.685	22.0	11.085	22.7	11.515	24.4	12.075
20.1	9.770	20.6	10.255	21.5	10.695	22.0	11.095	22.7	11.535	24.1	12.090
20.3	9.780	21.0	10.265	21.6	10.705	21.8	11.105	22.8	11.555	24.4	12.100
20.0	9.790	20.7	10.265	21.6	10.715	21.8	11.115	22.9	11.570	24.3	12.110
19.6	9.795	20.4	10.275	21.4	10.725	21.3	11.125	23.0	11.585	23.7	12.120
19.6	9.800	20.8	10.285	21.6	10.735	21.5	11.135	22.7	11.595	24.0	12.130
19.5	9.805	20.6	10.295	21.7	10.745	21.3	11.145	22.8	11.600	24.1	12.140
19.7	9.820	20.7	10.305	21.6	10.755	21.8	11.155	22.9	11.610	23.7	12.150
19.4	9.830	20.6	10.315	21.8	10.760	21.4	11.155	22.7	11.625	23.8	12.160
19.8	9.840	20.8	10.325	21.3	10.770	21.6	11.165	22.5	11.635	23.6	12.170
19.9	9.850	20.8	10.325	21.5	10.780	21.5	11.175	22.7	11.645	23.8	12.180
20.0	9.870	20.9	10.335	21.3	10.790	21.7	11.185	22.9	11.660	24.0	12.190
20.5	9.885	20.7	10.345	21.4	10.795	21.7	11.205	23.1	11.675	23.8	12.200
20.4	9.905	20.4	10.350	21.4	10.800	21.8	11.215	23.4	11.695	24.0	12.220
20.6	9.925	20.3	10.355	21.0	10.810	21.7	11.230	23.6	11.705	23.6	12.220
21.5	9.945	20.2	10.365	21.2	10.820	21.8	11.245	23.3	11.720	24.1	12.245
21.1	9.955	20.2	10.370	20.9	10.825	21.7	11.250	23.6	11.730	24.5	12.260
20.8	9.965	19.8	10.375	21.2	10.835	21.3	11.265	23.2	11.740	23.9	12.280
20.8	9.975	20.0	10.385	21.1	10.840	21.6	11.270	23.0	11.750	24.3	12.290
20.9	9.995	20.1	10.390	20.8	10.850	21.4	11.280	23.0	11.760	24.2	12.310
20.8	10.005	20.5	10.400	21.0	10.860	21.7	11.285	23.1	11.775	25.0	12.325
20.8	10.015	20.2	10.410	20.8	10.870	21.9	11.300	23.3	11.790	24.6	12.345

Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
24.6	12.355	26.2	12.970	28.5	13.765	30.3	14.615	29.1	15.210	30.4	15.870
24.3	12.365	26.3	12.990	28.7	13.795	30.6	14.635	29.0	15.230	30.4	15.900
24.0	12.370	26.7	13.005	29.0	13.815	30.4	14.650	29.2	15.240	31.0	15.915
24.0	12.385	26.2	13.020	29.2	13.840	30.1	14.670	29.2	15.260	30.9	15.940
24.4	12.405	25.9	13.030	29.0	13.855	30.3	14.685	28.9	15.270	30.7	15.955
24.9	12.435	26.3	13.050	28.7	13.875	30.4	14.710	28.7	15.280	30.7	15.975
25.1	12.445	26.8	13.075	28.9	13.885	30.3	14.725	28.8	15.295	30.7	15.985
25.2	12.465	27.0	13.100	28.7	13.895	30.0	14.735	28.8	15.310	30.0	15.995
25.5	12.480	27.4	13.120	29.0	13.915	30.1	14.745	29.2	15.320	30.1	16.010
25.2	12.505	27.5	13.145	29.6	13.950	29.6	14.765	28.8	15.340	30.7	16.035
25.4	12.515	27.3	13.160	29.8	13.980	29.4	14.775	28.9	15.350	30.7	16.055
24.9	12.525	27.3	13.190	30.1	14.015	29.4	14.790	28.7	15.365	31.0	16.080
25.1	12.535	27.1	13.200	29.8	14.035	29.9	14.805	28.8	15.380	30.9	16.100
24.7	12.545	27.3	13.210	30.2	14.065	29.4	14.825	29.1	15.400	31.2	16.125
25.3	12.565	27.3	13.230	30.2	14.075	29.7	14.835	29.5	15.420	30.8	16.135
25.9	12.595	27.7	13.260	29.8	14.090	29.6	14.855	30.0	15.455	30.8	16.155
26.1	12.615	27.7	13.280	29.9	14.110	29.8	14.865	30.1	15.480	30.4	16.160
26.2	12.640	27.8	13.310	30.6	14.145	29.4	14.885	30.1	15.495	30.5	16.180
26.0	12.655	28.5	13.330	30.5	14.165	29.3	14.890	30.0	15.510	30.4	16.190
26.2	12.675	28.4	13.360	30.4	14.195	28.9	14.905	29.4	15.520	30.4	16.210
25.8	12.690	28.6	13.380	30.7	14.215	28.6	14.905	30.0	15.535	30.7	16.225
26.0	12.705	27.8	13.390	30.4	14.235	29.0	14.925	29.2	15.550	31.3	16.255
25.8	12.715	28.5	13.420	30.6	14.250	29.1	14.935	29.6	15.560	31.3	16.275
25.8	12.725	28.8	13.450	30.3	14.265	28.9	14.955	29.4	15.585	31.2	16.305
25.6	12.735	29.1	13.475	29.8	14.285	28.9	14.965	29.8	15.600	30.9	16.310
25.7	12.755	29.2	13.505	30.1	14.310	29.3	14.985	29.7	15.620	31.0	16.330
25.4	12.765	29.2	13.520	30.4	14.325	28.9	14.995	29.9	15.635	30.8	16.350
25.6	12.775	28.7	13.540	31.0	14.365	29.1	15.015	29.8	15.655	31.1	16.370
25.3	12.790	28.6	13.550	31.5	14.395	29.0	15.025	29.7	15.665	31.3	16.390
25.9	12.805	28.3	13.560	32.0	14.440	28.8	15.040	29.6	15.675	31.2	16.410
26.3	12.825	28.0	13.575	31.2	14.450	28.7	15.050	30.1	15.695	31.4	16.430
26.1	12.835	28.7	13.610	31.1	14.470	28.5	15.055	30.1	15.725	31.2	16.445
25.8	12.855	28.9	13.630	30.9	14.480	28.7	15.075	29.9	15.735	30.9	16.455
25.9	12.870	28.9	13.660	30.9	14.500	28.9	15.095	30.2	15.755	30.8	16.470
25.2	12.875	29.3	13.675	30.9	14.510	28.9	15.110	30.2	15.775	30.7	16.480
25.6	12.895	29.0	13.700	30.2	14.530	29.9	15.140	30.1	15.795	30.8	16.500
25.9	12.905	29.0	13.710	30.4	14.545	29.7	15.160	29.9	15.805	30.6	16.510
25.9	12.920	28.6	13.720	30.9	14.570	29.9	15.180	29.9	15.825	30.5	16.530
25.7	12.935	28.6	13.730	30.7	14.585	29.3	15.190	29.6	15.830	31.0	16.540
26.3	12.960	28.7	13.750	30.6	14.605	29.3	15.200	29.9	15.850	31.1	16.570

APPENDIX C – Experimental data of the blocks

Experimental data from the lightweight concrete blocks tested at ambient temperature.

Ambient temperature											
Block 1		Block 2		Block 3		Block 4		Block 5		Block 6	
Load KN	Deflec mm	Load KN	Deflec mm	Load KN	Deflec mm	Load KN	Deflec mm	Load KN	Deflec mm	Load KN	Deflec mm
0.0	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	0.000
97.5	0.580	103.0	0.566	92.4	0.524	101.1	0.552	102.1	0.573	101.0	0.552
101.6	0.601	103.0	0.573	96.7	0.548	101.1	0.556	108.0	0.609	105.7	0.580
106.5	0.629	104.9	0.585	104.4	0.589	106.7	0.586	111.3	0.624	113.0	0.616
106.9	0.638	107.1	0.600	105.4	0.608	107.8	0.596	117.2	0.659	115.6	0.633
110.2	0.654	109.3	0.614	114.6	0.650	110.0	0.609	118.9	0.671	119.8	0.659
111.8	0.666	117.5	0.655	117.1	0.669	114.1	0.630	127.6	0.716	121.8	0.672
118.6	0.700	119.3	0.668	121.2	0.689	121.0	0.665	128.1	0.724	127.9	0.702
120.0	0.711	126.7	0.702	125.1	0.713	122.3	0.674	133.8	0.749	128.5	0.712
126.4	0.746	128.5	0.714	127.2	0.726	128.6	0.704	134.6	0.759	136.0	0.745
128.4	0.760	133.8	0.737	134.1	0.759	133.8	0.732	140.5	0.786	142.5	0.780
132.5	0.783	137.3	0.758	133.7	0.766	134.6	0.739	140.9	0.794	141.7	0.787
139.8	0.819	139.8	0.772	140.8	0.800	140.9	0.770	147.3	0.821	149.2	0.817
141.8	0.840	147.8	0.804	145.9	0.827	145.7	0.796	151.1	0.844	154.8	0.844
145.0	0.859	151.7	0.826	147.6	0.840	147.1	0.808	153.1	0.858	155.7	0.858
151.6	0.897	154.1	0.839	154.6	0.873	152.7	0.837	160.0	0.890	162.3	0.886
158.4	0.929	157.7	0.859	159.8	0.903	158.7	0.865	160.3	0.900	169.1	0.919
158.7	0.944	160.9	0.875	160.8	0.916	162.0	0.884	166.6	0.928	174.5	0.949
165.0	0.980	166.8	0.904	167.7	0.950	164.9	0.903	171.1	0.954	176.7	0.969
170.9	1.010	167.2	0.912	174.0	0.982	170.5	0.931	173.7	0.972	182.1	0.996
171.9	1.025	174.3	0.943	175.1	1.001	177.0	0.964	178.3	0.997	188.7	1.029
177.0	1.057	180.5	0.973	179.3	1.022	182.7	0.997	184.5	1.033	195.4	1.066
183.7	1.094	180.9	0.984	185.6	1.055	189.4	1.028	189.9	1.065	198.1	1.087
190.9	1.134	187.8	1.016	192.1	1.093	193.4	1.055	191.8	1.088	200.9	1.106
194.8	1.165	193.1	1.045	192.2	1.107	195.5	1.077	195.7	1.113	207.0	1.161
196.3	1.187	197.5	1.072	197.7	1.133	199.1	1.101	201.6	1.150	211.1	1.179
202.0	1.229	201.2	1.089	203.8	1.166	205.5	1.136	208.2	1.189	214.2	1.206
207.9	1.266	207.0	1.121	209.7	1.199	211.5	1.170	213.0	1.227	218.8	1.236
213.3	1.311	208.9	1.141	212.3	1.225	216.0	1.234	216.4	1.262	224.7	1.277
219.6	1.360	213.3	1.165	215.0	1.248	222.9	1.259	219.2	1.298	231.7	1.318
224.3	1.405	219.4	1.201	221.7	1.286	228.4	1.295	223.0	1.335	237.4	1.360
227.7	1.451	226.0	1.246	227.3	1.324	233.4	1.331	228.7	1.383	243.3	1.402
230.5	1.497	230.6	1.279	229.9	1.355	239.4	1.376	233.2	1.440	249.4	1.453
233.0	1.541	231.6	1.301	231.8	1.385	241.4	1.401	237.6	1.480	252.8	1.489
237.3	1.595	237.6	1.336	237.0	1.430	246.0	1.445	239.1	1.521	257.7	1.544

Block 1		Block 2		Block 3		Block 4		Block 5		Block 6	
Load KN	Deflec mm	Load KN	Deflec mm	Load KN	Deflec mm	Load KN	Deflec mm	Load KN	Deflec mm	Load KN	Deflec mm
240.5	1.659	243.6	1.378	243.1	1.471	251.7	1.491	238.5	1.574	260.3	1.588
243.1	1.733	248.6	1.421	248.6	1.517	256.9	1.538	237.1	1.649	263.8	1.637
235.2	1.902	254.6	1.460	253.4	1.565	261.7	1.584	228.9	1.799	265.8	1.695
		258.2	1.497	257.2	1.610	268.7	1.638			268.8	1.759
		260.3	1.531	258.5	1.653	273.9	1.692			269.9	1.833
		264.8	1.570	258.5	1.685	277.6	1.746				
		270.0	1.614	263.2	1.730	282.6	1.807				
		275.8	1.663	261.8	1.757	285.6	1.870				
		280.4	1.713	265.5	1.809	287.0	1.960				
		285.4	1.771	268.8	1.870	286.7	2.036				
		289.3	1.828	268.6	1.946						
		292.1	1.893	259.8	2.017						
		291.2	1.990								
		281.0	8.860								

Experimental data from the lightweight concrete blocks tested at 200ºC.

Block 1		Block 2		Block 3		Block 4		Block 5	
Load KN	Deflec mm	Load KN	Deflec mm	Load KN	Deflec mm	Load KN	Deflec mm	Load KN	Deflec mm
0.0	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	0.0
102.7	1.008	101.6	1.012	97.7	1.170	86.0	0.901	95.0	0.8
101.4	1.021	112.1	1.097	100.1	1.194	90.6	0.954	95.7	0.9
103.3	1.038	119.1	1.167	100.9	1.212	91.4	0.971	103.4	0.9
104.9	1.057	120.0	1.180	100.2	1.215	94.9	1.011	102.9	1.0
104.6	1.062	118.7	1.189	100.7	1.225	98.6	1.049	112.2	1.0
106.6	1.076	121.1	1.207	102.8	1.244	101.9	1.082	118.6	1.1
108.0	1.096	122.3	1.222	104.1	1.261	104.1	1.109	118.2	1.1
109.5	1.117	122.8	1.230	105.0	1.273	104.1	1.122	123.7	1.1
115.6	1.164	123.5	1.242	104.8	1.282	108.0	1.151	126.6	1.2
121.5	1.217	125.0	1.251	105.0	1.284	108.3	1.168	127.4	1.2
127.7	1.273	127.0	1.263	108.9	1.321	111.9	1.192	133.4	1.2
132.3	1.320	126.5	1.273	112.1	1.350	112.4	1.209	136.9	1.2
131.8	1.340	131.4	1.299	111.3	1.356	117.2	1.246	139.8	1.3
136.2	1.380	130.6	1.304	116.8	1.408	122.0	1.283	148.2	1.3
141.0	1.426	135.3	1.335	118.0	1.435	125.3	1.318	148.5	1.4
145.4	1.465	134.7	1.338	117.6	1.439	126.6	1.346	153.0	1.4
149.4	1.515	136.4	1.358	121.3	1.469	129.8	1.377	158.7	1.4
153.2	1.563	139.3	1.377	122.1	1.483	134.4	1.422	164.1	1.5
157.5	1.615	139.4	1.389	121.8	1.495	138.2	1.466	168.8	1.5
160.5	1.667	143.7	1.413	126.5	1.523	142.4	1.512	173.6	1.6
163.5	1.717	145.0	1.437	125.5	1.534	151.2	1.577	177.3	1.6
165.8	1.772	146.9	1.450	127.3	1.549	154.1	1.613	181.5	1.7
168.8	1.834	147.2	1.457	130.4	1.572	159.3	1.662	186.3	1.7
171.1	1.916	149.5	1.479	129.5	1.581	163.3	1.704	191.1	1.7
		151.2	1.495	135.1	1.621	166.1	1.754	194.6	1.8
		153.1	1.514	134.3	1.629	169.4	1.806	198.4	1.9
		155.1	1.532	139.2	1.674	172.4	1.856	201.4	1.9
		156.4	1.547	138.1	1.677	176.5	1.918	205.4	2.0
		159.6	1.566	142.8	1.715	182.3	1.986	205.3	2.1
		160.2	1.585	142.3	1.725	186.1	2.056	208.3	2.1
		163.8	1.606	147.0	1.762	186.0	2.137	204.8	2.2
		164.4	1.626	146.5	1.773	184.0	2.315	202.6	2.2
		167.7	1.651	151.3	1.819				
		170.0	1.668	150.7	1.823				
		172.3	1.690	155.8	1.865				
		174.4	1.713	155.1	1.886				

Block 1		Block 2		Block 3		Block 4		Block 5	
Load KN	Deflec mm	Load KN	Deflec mm	Load KN	Deflec mm	Load KN	Deflec mm	Load KN	Deflec mm
176.8	1.730	159.2	1.920						
179.9	1.760	160.0	1.947						
181.0	1.785	161.7	1.989						
185.6	1.807	166.4	2.066						
185.0	1.819	165.9	2.036						
190.5	1.854	170.9	2.067						
189.4	1.864	169.7	2.085						
194.2	1.898	173.7	2.116						
197.6	1.932	177.2	2.161						
198.6	1.943	176.2	2.169						
198.4	1.960	180.0	2.209						
202.6	1.988	182.5	2.249						
203.6	2.013	182.4	2.271						
206.8	2.036	186.0	2.321						
210.6	2.077	187.4	2.301						
211.0	2.083	185.5	2.304						
213.1	2.113	187.0	2.342						
214.3	2.135	185.2	2.394						
218.3	2.172	180.1	2.484						
218.1	2.188								
222.0	2.235								
221.2	2.243								
226.4	2.288								
224.6	2.304								
229.3	2.345								
227.2	2.366								
229.7	2.424								
229.6	2.442								
231.1	2.495								
227.6	2.560								

Experimental data from the lightweight concrete blocks tested at 400ºC.

Block 1		Block 2		Block 3		Block 4		Block 5	
Load KN	Deflec mm	Load KN	Deflec mm	Load KN	Deflec mm	Load KN	Deflec mm	Load KN	Deflec mm
0.0	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	0.000
101.5	1.106	85.3	1.491	102.7	1.203	100.3	1.061	93.3	1.227
100.4	1.125	87.3	1.579	105.5	1.228	101.1	1.079	100.7	1.304
101.9	1.145	95.6	1.706	109.9	1.272	106.5	1.124	100.9	1.327
104.5	1.171	105.5	1.844	115.3	1.328	109.2	1.166	109.6	1.421
104.3	1.181	106.9	1.890	119.8	1.400	115.8	1.243	109.8	1.453
108.3	1.210	109.1	1.943	127.8	1.473	123.4	1.313	116.5	1.522
108.7	1.224	116.0	2.013	130.6	1.523	131.9	1.386	122.4	1.586
111.7	1.251	117.6	2.061	133.6	1.552	133.1	1.406	128.0	1.639
112.8	1.266	120.2	2.104	138.0	1.593	137.4	1.445	128.7	1.669
116.8	1.300	124.6	2.167	142.9	1.638	139.6	1.474	132.3	1.712
117.4	1.329	128.4	2.222	147.3	1.684	142.8	1.509	136.0	1.746
123.2	1.376	131.4	2.274	151.7	1.730	146.1	1.545	141.1	1.798
127.9	1.431	135.7	2.327	155.7	1.777	150.6	1.584	145.6	1.842
132.3	1.479	137.9	2.366	160.3	1.827	155.9	1.631	150.4	1.888
140.6	1.560	140.0	2.408	165.4	1.877	160.2	1.674	154.0	1.933
144.2	1.599	141.1	2.444	168.8	1.926	164.5	1.720	158.7	1.984
150.4	1.657	144.5	2.495	173.5	1.976	169.1	1.765	159.3	2.009
154.1	1.710	148.4	2.538	177.6	2.047	173.0	1.812	164.4	2.056
157.5	1.768	149.5	2.574	180.4	2.086	178.0	1.854	166.0	2.086
166.4	1.843	150.1	2.609	186.5	2.160	182.6	1.903	169.8	2.134
170.2	1.909	151.9	2.654	193.3	2.229	186.0	1.967	171.6	2.171
174.4	1.981	155.1	2.710	198.0	2.286	189.5	2.000	177.8	2.231
181.2	2.068	157.0	2.769	200.4	2.345	194.2	2.044	180.6	2.262
182.4	2.143	158.0	2.846	202.5	2.409	198.2	2.092	184.2	2.314
185.9	2.245	158.2	2.935	207.2	2.481	202.4	2.143	189.1	2.370
187.3	2.372	153.9	3.084	209.7	2.547	207.0	2.196	194.3	2.433
187.6	2.468			215.5	2.636	210.1	2.252	200.3	2.502
				211.7	2.765	212.4	2.319	201.9	2.574
						219.6	2.430	204.2	2.646
						220.7	2.504	210.5	2.752
						218.0	2.613	207.5	2.856
								205.6	3.031

Experimental data from the lightweight concrete blocks tested at 600ºC.

Block 1		Block 2		Block 3		Block 4		Block 5		Block6	
Load KN	Deflec mm	Load KN	Deflec mm	Load KN	Deflec mm	Load KN	Deflec mm	Load KN	Deflec mm	Load KN	Deflec mm
0.0	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	0.000
73.1	1.187	76.7	1.027	74.1	1.067	95.2	1.296	77.9	1.105	76.9	1.226
83.2	1.379	81.3	1.160	94.7	1.360	97.3	1.356	86.7	1.227	86.8	1.381
100.9	1.648	91.3	1.330	103.9	1.519	100.9	1.404	86.0	1.252	95.5	1.539
114.5	1.835	100.3	1.429	111.2	1.644	101.5	1.433	91.0	1.314	102.6	1.639
114.2	1.863	108.0	1.531	116.5	1.696	106.7	1.490	91.8	1.339	102.5	1.700
117.6	1.910	106.4	1.556	116.5	1.724	106.2	1.506	90.8	1.355	105.7	1.745
121.1	1.955	108.3	1.586	118.7	1.752	112.8	1.583	95.0	1.393	105.6	1.768
120.3	1.975	109.3	1.610	123.3	1.797	119.3	1.658	97.0	1.426	111.1	1.821
122.4	2.005	109.8	1.631	127.3	1.840	123.2	1.716	99.7	1.480	110.4	1.856
123.4	2.033	111.2	1.649	129.5	1.878	127.9	1.777	108.3	1.605	116.6	1.908
125.8	2.061	112.3	1.669	129.5	1.894	131.5	1.839	116.1	1.673	121.6	1.974
127.6	2.086	118.7	1.723	133.9	1.936	135.5	1.883	120.9	1.733	120.6	2.003
132.2	2.132	123.6	1.780	138.2	1.982	139.5	1.927	125.5	1.798	124.8	2.048
133.5	2.163	123.4	1.809	141.1	2.022	142.6	1.979	128.0	1.851	126.7	2.082
135.0	2.198	128.8	1.879	144.8	2.062	145.8	2.026	130.8	1.895	130.6	2.136
139.4	2.264	131.9	1.912	148.7	2.110	145.3	2.056	134.5	1.958	131.8	2.161
142.3	2.306	135.8	1.968	149.7	2.138	147.2	2.092	139.7	2.001	135.4	2.214
146.3	2.358	140.5	2.029	153.1	2.178	151.1	2.135	144.7	2.050	138.7	2.272
149.2	2.408	146.0	2.097	155.1	2.212	158.7	2.213	147.8	2.099	143.5	2.335
152.3	2.460	151.5	2.159	158.9	2.253	162.4	2.275	148.4	2.130	147.9	2.394
155.0	2.518	156.9	2.229	163.0	2.295	164.9	2.351	151.5	2.171	153.9	2.470
158.3	2.590	161.9	2.281	165.9	2.342	173.0	2.434	155.4	2.226	154.7	2.507
161.3	2.640	165.2	2.338	170.4	2.379	178.9	2.539	160.8	2.273	160.8	2.573
166.1	2.717	167.3	2.390	173.7	2.426	182.9	2.603	165.2	2.326	164.0	2.630
170.5	2.794	171.5	2.443	177.4	2.476	183.5	2.691	169.6	2.380	167.7	2.685
173.1	2.863	180.2	2.524	181.1	2.533	190.0	2.788	173.8	2.437	169.9	2.740
173.7	2.939	184.5	2.600	189.4	2.605	191.1	2.904	177.0	2.493	177.7	2.839
175.7	3.063	187.9	2.656	193.0	2.670	193.2	3.043	181.2	2.572	180.5	2.893
174.5	3.173	196.2	2.744	196.9	2.718			184.0	2.612	184.1	2.961
		200.2	2.813	200.1	2.777			188.0	2.679	186.2	3.029
		202.6	2.884	206.4	2.850			196.6	2.757	192.7	3.128
		210.7	2.975	212.8	2.918			200.0	2.830	195.7	3.206
		214.3	3.071	215.2	2.977			202.7	2.886	201.5	3.326
		219.0	3.138	223.3	3.078			209.8	2.985	203.4	3.394
		221.7	3.212	227.5	3.133			213.6	3.038	205.8	3.500
		226.5	3.295	228.1	3.197			215.1	3.105	208.7	3.604

Block 1		Block 2		Block 3		Block 4		Block 5		Block6	
Load KN	Deflec mm	Load KN	Deflec mm	Load KN	Deflec mm	Load KN	Deflec mm	Load KN	Deflec mm	Load KN	Deflec mm
		229.4	3.388	232.3	3.273			219.1	3.202	212.7	3.751
		234.4	3.477	237.0	3.343			223.2	3.261		
		239.0	3.610	239.9	3.407			226.8	3.355		
		239.6	3.689	241.7	3.491			230.2	3.454		
		242.1	3.809	246.1	3.555			233.0	3.521		
		238.3	3.907	247.5	3.628			238.0	3.640		
				252.9	3.727			236.1	3.748		
				251.1	3.829						

Experimental data from the lightweight concrete blocks tested at 800ºC.

Block 1		Block 2		Block 3		Block 4		Block 5		Block6	
Load KN	Deflec mm	Load KN	Deflec mm	Load KN	Deflec mm	Load KN	Deflec mm	Load KN	Deflec mm	Load KN	Deflec mm
0.0	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	0.0
37.7	2.395	29.4	2.560	34.3	1.826	24.6	2.030	24.1	1.464	21.3	1.2
46.1	2.780	37.7	3.245	48.1	2.495	36.7	3.103	36.9	2.326	32.1	1.9
54.1	3.318	44.2	3.970	67.3	3.181	42.0	3.587	48.1	3.060	42.0	2.5
63.3	3.818	54.6	4.580	78.2	3.804	53.8	4.377	59.2	3.765	50.5	3.0
72.2	4.297	66.8	5.360	98.4	4.510	65.7	5.108	70.9	4.430	60.6	3.6
81.8	4.789	62.6	5.735	99.4	4.928	68.8	5.739	74.7	5.214	77.3	4.2
97.9	5.414	73.3	6.350	103.9	5.414	81.0	6.357	84.1	5.676	81.8	4.6
100.8	5.804	80.3	6.935	103.6	5.956	83.5	7.105	84.2	6.211	85.1	5.0
108.0	6.284	80.6	7.550	109.9	6.470	86.5	7.579	90.9	6.824	87.3	5.3
103.3	6.604	74.8	8.195	101.4	6.978	79.2	8.184	85.0	7.430	87.3	5.5
107.9	7.000	67.5	9.155	93.9	7.668	83.9	8.854	85.0	7.979	81.2	5.6
109.4	7.466	44.7	9.750	80.2	8.008	69.8	9.489	75.9	8.751	81.6	5.8
107.6	8.191	27.8	10.570	73.1	8.447	62.0	10.291	69.9	9.273	85.9	6.0
91.8	8.656	19.2	11.115	62.2	8.737	32.7	11.234	59.9	9.961	87.5	6.2
69.5	9.454	14.1	11.450	54.9	8.998	23.6	11.715	50.1	10.744	97.2	6.5
51.0	9.964			46.1	9.083	15.4	12.123	36.8	11.363	99.2	6.7
47.3	10.458					11.6	12.621	28.4	11.589	97.4	7.0
34.6	10.641					7.3	12.913	21.4	11.746	109.3	7.4
								19.1	11.790	105.6	7.6
										108.0	7.9
										108.1	8.2
										108.3	8.6
										107.7	9.0
										101.5	9.5
										99.9	9.9
										87.5	10.4
										80.2	11.1
										62.8	11.7
										47.0	12.2
										29.3	12.6
										27.5	12.8
										20.4	12.9

APPENDIX D – Thermal numerical input data

Thermal analysis data of wallettes at 200ºC

```
*Elset, elset=_Hot_faces_S2, internal, instance=Half_block-1, generate
  1, 100,   1
*Elset, elset=_Hot_faces_S2, internal, instance=Half_block-3, generate
  1, 100,   1
*Elset, elset=_Hot_faces_S2, internal, instance=Mortar-1, generate
 1233,  1540,    1
*Elset, elset=_Hot_faces_S4, internal, instance=Half_block-1, generate
   5,  2000,    5
*Elset, elset=_Hot_faces_S4, internal, instance=Half_block-2, generate
   5,  2000,    5
*Elset, elset=_Hot_faces_S4, internal, instance=Half_block-3, generate
   5,  2000,    5
*Elset, elset=_Hot_faces_S4, internal, instance=Mortar-1
  62,   97,  164,  204,  241,  283,  306,  370,  405,  472,  512,  549,  591,  614,  678,  713
 780,  820,  857,  899,  922,  986, 1021, 1088, 1128, 1165, 1207, 1230, 1294, 1329, 1396, 1436
 1473, 1515, 1538
*Elset, elset=_Hot_faces_S6, internal, instance=Half_block-1, generate
   1,  1996,    5
*Elset, elset=_Hot_faces_S6, internal, instance=Half_block-2, generate
   1,  1996,    5
*Elset, elset=_Hot_faces_S6, internal, instance=Half_block-3, generate
   1,  1996,    5
*Elset, elset=_Hot_faces_S6, internal, instance=Mortar-1, generate
   1,  1233,   308
*Surface, type=ELEMENT, name=Hot_faces
_Hot_faces_S1, S1
_Hot_faces_S5, S5
_Hot_faces_S2, S2
_Hot_faces_S4, S4
_Hot_faces_S6, S6
_Hot_faces_S3, S3
*Elset, elset=_Bottom_mortar_S3, internal, instance=Mortar-1
 222,  223,  224,  225,  226,  227,  228,  229,  230,  231,  232,  233,  234,  235,  236,  237
 238,  239,  240,  241,  530,  531,  532,  533,  534,  535,  536,  537,  538,  539,  540,  541
 542,  543,  544,  545,  546,  547,  548,  549,  838,  839,  840,  841,  842,  843,  844,  845
 846,  847,  848,  849,  850,  851,  852,  853,  854,  855,  856,  857, 1146, 1147, 1148, 1149
 1150,  1151,  1152,  1153,  1154,  1155,  1156,  1157,  1158,  1159,  1160,  1161,  1162,  1163,  1164,
1165
 1454,  1455,  1456,  1457,  1458,  1459,  1460,  1461,  1462,  1463,  1464,  1465,  1466,  1467,  1468,
1469
 1470, 1471, 1472, 1473
*Elset, elset=_Bottom_mortar_S4, internal, instance=Mortar-1, generate
 242,  1474,   308
*Elset, elset=_Bottom_mortar_S5, internal, instance=Mortar-1
 243,  244,  245,  246,  247,  248,  249,  250,  251,  252,  253,  254,  255,  256,  257,  258
 259,  260,  261,  262,  263,  264,  265,  266,  267,  268,  269,  270,  271,  272,  273,  274
 275,  276,  277,  278,  279,  280,  281,  282,  283,  551,  552,  553,  554,  555,  556,  557
 558,  559,  560,  561,  562,  563,  564,  565,  566,  567,  568,  569,  570,  571,  572,  573
 574,  575,  576,  577,  578,  579,  580,  581,  582,  583,  584,  585,  586,  587,  588,  589
 590,  591,  859,  860,  861,  862,  863,  864,  865,  866,  867,  868,  869,  870,  871,  872
 873,  874,  875,  876,  877,  878,  879,  880,  881,  882,  883,  884,  885,  886,  887,  888
 889,  890,  891,  892,  893,  894,  895,  896,  897,  898,  899, 1167, 1168, 1169, 1170, 1171
 1172,  1173,  1174,  1175,  1176,  1177,  1178,  1179,  1180,  1181,  1182,  1183,  1184,  1185,  1186,
1187
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 1188, 1189, 1190, 1191, 1192, 1193, 1194, 1195, 1196, 1197, 1198, 1199, 1200, 1201, 1202,
1203
 1204, 1205, 1206, 1207, 1475, 1476, 1477, 1478, 1479, 1480, 1481, 1482, 1483, 1484, 1485,
1486
 1487, 1488, 1489, 1490, 1491, 1492, 1493, 1494, 1495, 1496, 1497, 1498, 1499, 1500, 1501,
1502
 1503, 1504, 1505, 1506, 1507, 1508, 1509, 1510, 1511, 1512, 1513, 1514, 1515
*Surface, type=ELEMENT, name=Bottom_mortar
_Bottom_mortar_S3, S3
_Bottom_mortar_S4, S4
_Bottom_mortar_S5, S5
** Constraint: Constraint-1
*Tie, name=Constraint-1, adjust=yes, type=SURFACE TO SURFACE
Mortar, Surf-27(Blocks)
*End Assembly
*Amplitude, name=Furnace_temperature
      0.,      20.595,       30.,       21.3,       60.,      24.96,       90.,     33.125
    120.,       45.42,      150.,      59.72,      180.,      73.24,      210.,     84.205
    240.,      89.425,      270.,      91.17,      300.,      90.93,      330.,     90.995
    360.,      93.365,      390.,      98.89,      420.,    105.835,      450.,    113.445
    480.,     119.685,      510.,    122.385,      540.,     122.27,      570.,    123.795
    600.,      128.73,      630.,     135.48,      660.,    142.995,      690.,    147.685
    720.,     151.135,      750.,    152.265,      780.,    154.245,      810.,     159.26
    840.,      165.61,      870.,     172.94,      900.,    179.225,      930.,      180.6
    960.,      178.38,      990.,    179.885,     1020.,    186.135,     1050.,      193.8
   1080.,      201.49,     1110.,    207.095,     1140.,    205.745,     1170.,      203.1
   1200.,     199.255,     1230.,     195.83,     1260.,     191.83,     1290.,    188.555
   1320.,     185.035,     1350.,    182.295,     1380.,    179.965,     1410.,    178.205
   1440.,      178.62,     1470.,      181.3,     1500.,    184.515,     1530.,    189.365
   1560.,        194.,     1590.,    196.675,     1620.,    198.815,     1650.,     199.58
   1680.,       198.6,     1710.,    196.935,     1740.,     193.75,     1770.,    191.325
   1800.,      190.83,     1830.,    193.475,     1860.,     197.55,     1890.,     198.19
   1920.,     196.775,     1950.,    194.795,     1980.,    192.475,     2010.,     191.08
   2040.,      193.88,     2070.,    198.035,     2100.,    198.855,     2130.,     197.93
   2160.,     196.035,     2190.,    194.145,     2220.,    192.345,     2250.,      191.7
   2280.,      194.91,     2310.,    198.145,     2340.,      198.7,     2370.,    197.545
   2400.,     196.025,     2430.,    194.155,     2460.,    192.595,     2490.,     193.73
   2520.,     197.195,     2550.,     198.07,     2580.,    197.495,     2610.,    196.205
   2640.,     194.395,     2670.,     193.48,     2700.,     194.39,     2730.,     197.55
   2760.,     199.135,     2790.,    198.325,     2820.,    197.435,     2850.,     199.26
   2880.,      203.77,     2910.,     206.96,     2940.,    206.135,     2970.,     204.95
   3000.,     203.155,     3030.,    200.955,     3060.,     199.31,     3090.,     197.36
   3120.,     196.105,     3150.,     195.51,     3180.,     196.26,     3210.,    197.435
   3240.,     200.085,     3270.,    201.305,     3300.,    202.265,     3330.,     202.25
   3360.,       200.9,     3390.,    199.695,     3420.,     199.07,     3450.,     199.31
   3480.,     200.905,     3510.,    202.445,     3540.,     202.54,     3570.,    201.705
   3600.,     200.485,     3630.,    199.405,     3660.,    199.835,     3690.,    200.575
   3720.,     201.955,     3750.,    202.665,     3780.,    202.005,     3810.,    200.595
   3840.,      199.49,     3870.,     199.38,     3900.,     200.96,     3930.,     202.49
   3960.,      203.13,     3990.,    202.765,     4020.,    201.555,     4050.,    200.365
   4080.,     200.325,     4110.,      201.2,     4140.,     202.92,     4170.,    203.825
   4200.,     203.365,     4230.,    203.125,     4260.,    202.085,     4290.,    200.585
   4320.,     200.045,     4350.,     201.64,     4380.,    203.345,     4410.,    203.855
   4440.,      202.87,     4470.,     202.35,     4500.,    200.955,     4530.,    200.855
   4560.,       201.6,     4590.,    203.395,     4620.,     204.13,     4650.,    203.645
   4680.,     202.975,     4710.,    201.965,     4740.,     200.59,     4770.,     201.34
   4800.,     203.485,     4830.,    204.545,     4860.,    203.545,     4890.,    203.125
   4920.,      201.38,     4950.,    201.245,     4980.,    202.485,     5010.,     204.66
   5040.,      204.96,     5070.,    204.675,     5100.,     203.47,     5130.,      202.2
   5160.,      200.98,     5190.,     201.12,     5220.,    202.975,     5250.,    205.265
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5280.,	205.39,	5310.,	204.79,	5340.,	203.85,	5370.,	202.505
5400.,	201.065,	5430.,	201.385,	5460.,	203.21,	5490.,	205.31
5520.,	205.445,	5550.,	205.385,	5580.,	204.055,	5610.,	202.8
5640.,	201.55,	5670.,	200.33,	5700.,	198.685,	5730.,	197.57
5760.,	198.97,	5790.,	203.2,	5820.,	205.11,	5850.,	205.205
5880.,	204.16,	5910.,	203.605,	5940.,	202.16,	5970.,	200.935
6000.,	199.43,	6030.,	198.685,	6060.,	200.305,	6090.,	203.935
6120.,	205.975,	6150.,	206.74,	6180.,	205.755,	6210.,	204.71
6240.,	203.3,	6270.,	202.12,	6300.,	200.7,	6330.,	199.815
6360.,	199.25,	6390.,	201.66,	6420.,	204.52,	6450.,	205.275
6480.,	205.385,	6510.,	204.31,	6540.,	203.25,	6570.,	201.985
6600.,	200.85,	6630.,	199.965,	6660.,	200.545,	6690.,	203.655
6720.,	204.99,	6750.,	204.915,	6780.,	204.165,	6810.,	203.38
6840.,	202.13,	6870.,	200.82,	6900.,	199.69,	6930.,	200.265
6960.,	203.755,	6990.,	205.03,	7020.,	205.825,	7050.,	205.045
7080.,	203.855,	7110.,	202.52,	7140.,	201.655,	7170.,	200.7
7200.,	199.715,	7230.,	201.55,	7260.,	204.605,	7290.,	206.175
7320.,	205.82,	7350.,	204.855,	7380.,	204.13,	7410.,	202.75
7440.,	201.705,	7470.,	200.465,	7500.,	200.55,	7530.,	203.21
7560.,	205.71,	7590.,	206.335,	7620.,	205.685,	7650.,	204.88
7680.,	203.91,	7710.,	202.945,	7740.,	201.78,	7770.,	200.84
7800.,	200.355,	7830.,	201.7,	7860.,	204.97,	7890.,	206.105
7920.,	206.01,	7950.,	205.465,	7980.,	204.28,	8010.,	203.345
8040.,	202.55,	8070.,	200.865,	8100.,	200.31,	8130.,	200.82
8160.,	203.305,	8190.,	205.64,	8220.,	206.07,	8250.,	205.05
8280.,	204.625,	8310.,	203.745,	8340.,	202.615,	8370.,	201.685
8400.,	200.725,	8430.,	201.24,	8460.,	204.055,	8490.,	204.85
8520.,	204.665,	8550.,	203.985,	8580.,	203.285,	8610.,	202.38
8640.,	201.4,	8670.,	201.745,	8700.,	204.305,	8730.,	206.32
8760.,	206.7,	8790.,	206.095,	8820.,	205.025,	8850.,	204.205
8880.,	203.465,	8910.,	202.245,	8940.,	200.985,	8970.,	200.25
9000.,	200.535,	9030.,	204.66,	9060.,	208.04,	9090.,	209.04
9120.,	208.31,	9150.,	207.675,	9180.,	206.655,	9210.,	205.615
9240.,	204.62,	9270.,	203.34,	9300.,	202.79,	9330.,	201.585
9360.,	200.61,	9390.,	200.09,	9420.,	199.515,	9450.,	199.32
9480.,	199.685,	9510.,	200.39,	9540.,	201.8,	9570.,	203.17
9600.,	204.01,	9630.,	204.39,	9660.,	204.825,	9690.,	204.89
9720.,	204.64,	9750.,	203.9,	9780.,	202.62,	9810.,	202.28
9840.,	202.295,	9870.,	202.88,	9900.,	203.165,	9930.,	203.605
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10080.,	203.375,	10110.,	202.55,	10140.,	202.56,	10170.,	203.055
10200.,	203.49,	10230.,	203.755,	10260.,	204.665,	10290.,	204.975
10320.,	205.18,	10350.,	204.555,	10380.,	203.685,	10410.,	202.845
10440.,	202.265,	10470.,	201.51,	10500.,	200.625,	10530.,	199.32
10560.,	198.74,	10590.,	198.995,	10620.,	201.05,	10650.,	203.87
10680.,	206.345,	10710.,	206.72,	10740.,	206.57,	10770.,	205.8
10800.,	204.75,	10830.,	203.75,	10860.,	202.855,	10890.,	201.965
10920.,	201.09,	10950.,	200.145,	10980.,	199.56,	11010.,	199.31
11040.,	199.37,	11070.,	199.785,	11100.,	200.22,	11130.,	200.69
11160.,	201.2,	11190.,	201.91,	11220.,	202.505,	11250.,	203.13
11280.,	203.765,	11310.,	204.025,	11340.,	203.94,	11370.,	203.5
11400.,	202.845,	11430.,	202.005,	11460.,	201.48,	11490.,	201.685
11520.,	202.1,	11550.,	202.675,	11580.,	203.59,	11610.,	203.86
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11760.,	202.58,	11790.,	202.97,	11820.,	203.89,	11850.,	203.99
11880.,	203.75,	11910.,	203.05,	11940.,	202.45,	11970.,	201.875
12000.,	201.77,	12030.,	202.085,	12060.,	202.73,	12090.,	203.325
12120.,	204.415,	12150.,	204.31,	12180.,	204.065,	12210.,	203.63
12240.,	202.77,	12270.,	202.,	12300.,	201.82,	12330.,	202.295
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12480.,	201.6,	12510.,	201.1,	12540.,	200.61,	12570.,	199.875
12600.,	199.28,	12630.,	198.91,	12660.,	199.315,	12690.,	202.065
12720.,	204.55,	12750.,	205.53,	12780.,	205.66,	12810.,	205.415
12840.,	204.395,	12870.,	203.87,	12900.,	203.05,	12930.,	202.03
12960.,	201.125,	12990.,	200.365,	13020.,	199.7,	13050.,	199.44
13080.,	201.94,	13110.,	204.07,	13140.,	204.985,	13170.,	205.05
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13320.,	201.435,	13350.,	200.67,	13380.,	200.015,	13410.,	200.18
13440.,	202.09,	13470.,	203.81,	13500.,	204.445,	13530.,	204.325
13560.,	203.995,	13590.,	203.37,	13620.,	202.685,	13650.,	201.86
13680.,	201.135,	13710.,	200.485,	13740.,	200.91,	13770.,	203.125
13800.,	204.78,	13830.,	205.085,	13860.,	205.005,	13890.,	204.38
13920.,	203.805,	13950.,	203.125,	13980.,	202.195,	14010.,	201.625
14040.,	201.035,	14070.,	200.985,	14100.,	202.765,	14130.,	204.085
14160.,	204.73,	14190.,	204.495,	14220.,	203.98,	14250.,	203.59
14280.,	202.74,	14310.,	201.955,	14340.,	201.275,	14370.,	200.505
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14520.,	205.14,	14550.,	204.88,	14580.,	204.065,	14610.,	203.335
14640.,	202.65,	14670.,	202.005,	14700.,	201.3,	14730.,	200.69
14760.,	202.185,	14790.,	204.855,	14820.,	205.865,	14850.,	206.185
14880.,	205.865,	14910.,	205.34,	14940.,	204.695,	14970.,	203.95
15000.,	203.055,	15030.,	202.31,	15060.,	201.615,	15090.,	200.89
15120.,	200.78,	15150.,	202.19,	15180.,	204.72,	15210.,	205.78
15240.,	206.045,	15270.,	205.465,	15300.,	204.855,	15330.,	204.065
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15600.,	203.575,	15630.,	203.31,	15660.,	202.675,	15690.,	202.105
15720.,	201.465,	15750.,	201.025,	15780.,	200.4,	15810.,	199.82
15840.,	199.205,	15870.,	198.85,	15900.,	200.305,	15930.,	204.06
15960.,	206.46,	15990.,	207.155,	16020.,	207.12,	16050.,	206.585
16080.,	206.09,	16110.,	205.37,	16140.,	204.555,	16170.,	203.6
16200.,	203.075,	16230.,	202.235,	16260.,	201.755,	16290.,	201.05
16320.,	200.465,	16350.,	199.79,	16380.,	199.2,	16410.,	199.01
16440.,	199.31,	16470.,	200.045,	16500.,	200.785,	16530.,	201.875
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16680.,	202.49,	16710.,	202.065,	16740.,	201.4,	16770.,	200.895
16800.,	200.245,	16830.,	200.005,	16860.,	200.465,	16890.,	201.61
16920.,	202.815,	16950.,	203.195,	16980.,	203.,	17010.,	202.375
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17400.,	201.465,	17430.,	200.855,	17460.,	200.15,	17490.,	200.35
17520.,	201.545,	17550.,	202.97,	17580.,	203.715,	17610.,	203.73
17640.,	203.28,	17670.,	202.83,	17700.,	202.385,	17730.,	201.77
17760.,	200.96,	17790.,	200.525,	17820.,	200.43,	17850.,	201.305
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18120.,	200.58,	18150.,	200.48,	18180.,	201.275,	18210.,	202.83
18240.,	204.205,	18270.,	204.505,	18300.,	204.29,	18330.,	203.795
18360.,	203.245,	18390.,	202.585,	18420.,	202.175,	18450.,	201.47
18480.,	201.145,	18510.,	200.75,	18540.,	201.14,	18570.,	202.535
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18720.,	202.705,	18750.,	202.185,	18780.,	201.525,	18810.,	200.975
18840.,	200.57,	18870.,	200.825,	18900.,	202.425,	18930.,	204.02
18960.,	204.24,	18990.,	204.26,	19020.,	203.925,	19050.,	203.445
19080.,	202.945,	19110.,	202.26,	19140.,	201.655,	19170.,	201.105
19200.,	200.685,	19230.,	201.305,	19260.,	202.8,	19290.,	203.32
19320.,	203.465,	19350.,	203.225,	19380.,	202.95,	19410.,	202.585
19440.,	202.035,	19470.,	201.575,	19500.,	201.18,	19530.,	201.53
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    20400.,     204.16,     20430.,     203.545,    20460.,     202.955,    20490.,     202.26
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    21600.,     202.015,    21630.,     201.475,    21660.,     201.38,     21690.,     203.3
    21720.,     204.61,     21750.,     205.11,     21780.,     205.38,     21810.,     205.08
    21840.,     204.61,     21870.,     204.175,    21900.,     203.445,    21930.,     203.005
    21960.,     202.53,     21990.,     202.06,     22020.,     201.53,     22050.,     201.39
    22080.,     202.535,    22110.,     204.235,    22140.,     204.965
**
** MATERIALS
**
*Material, name="Lightweight concrete"
*Conductivity
 0.33,200.
*Density
1400.,
*Latent Heat
48000.,100.,119.
*Specific Heat
660.,200.
*Material, name=Mortar_properties
*Conductivity
 2.9,200.
*Density
1900.,
*Latent Heat
89000.,100.,115.
*Specific Heat
7700.,200.
**
** INTERACTION PROPERTIES
**
*Film Property, name=Cold_face
4., 200.
*Film Property, name=Hot_face
25., 200.
**
** PHYSICAL CONSTANTS
**
*Physical Constants, absolute zero=-273., stefan boltzmann=5.67e-08
**
** PREDEFINED FIELDS
**
** Name: Predefined Field-1   Type: Temperature
*Initial Conditions, type=TEMPERATURE
_PickedSet2365, 19.
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**
** STEP: Heat transfer
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*Step, name="Heat transfer", inc=10000
*Heat Transfer, end=PERIOD, deltmx=10.
0.1, 22140., 0.001, 22140.,
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** INTERACTIONS
**
** Interaction: Bottom_cold_mortar
*Sfilm, amplitude=Furnace_temperature
Bottom_mortar, F, 1., Cold_face
** Interaction: External_hot_faces_specimen
*Sfilm, amplitude=Furnace_temperature
Hot_faces, F, 1., Hot_face
** Interaction: Internal_cold_block_faces
*Sfilm, amplitude=Furnace_temperature
Surf-27(Blocks), F, 1., Cold_face
** Interaction: Internal_cold_mortar_faces
*Sfilm, amplitude=Furnace_temperature
Mortar, F, 1., Cold_face
** Interaction: Radiation_Furnace_temperature
*Sradiate, amplitude=Furnace_temperature
Hot_faces, R, 1., 0.7
** Interaction: Radiation_bottom_mortar
*Sradiate
Bottom_mortar, R, 20., 0.7
** Interaction: Radiation_cold_top_mortar
*Sradiate
Top_mortar, R, 20., 0.7
** Interaction: Top_cold_mortar
*Sfilm, amplitude=Furnace_temperature
Top_mortar, F, 1., Cold_face
**
** OUTPUT REQUESTS
**
*Restart, write, frequency=0
**
** FIELD OUTPUT: F-Output-1
**
*Output, field, variable=PRESELECT
*Output, history, frequency=0
*End Step
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Thermal analysis data of wallettes at 400ºC

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*Elset, elset=_Hot_faces_S2, internal, instance=Half_block-1, generate
 1, 100,   1
*Elset, elset=_Hot_faces_S2, internal, instance=Half_block-3, generate
 1, 100,   1
*Elset, elset=_Hot_faces_S2, internal, instance=Mortar-1, generate
 1233,  1540,    1
*Elset, elset=_Hot_faces_S4, internal, instance=Half_block-1, generate
   5,  2000,    5
*Elset, elset=_Hot_faces_S4, internal, instance=Half_block-2, generate
   5,  2000,    5
*Elset, elset=_Hot_faces_S4, internal, instance=Half_block-3, generate
   5,  2000,    5
*Elset, elset=_Hot_faces_S4, internal, instance=Mortar-1
  62,   97,  164,  204,  241,  283,  306,  370,  405,  472,  512,  549,  591,  614,  678,  713
 780,  820,  857,  899,  922,  986, 1021, 1088, 1128, 1165, 1207, 1230, 1294, 1329, 1396, 1436
 1473, 1515, 1538
*Elset, elset=_Hot_faces_S6, internal, instance=Half_block-1, generate
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*Elset, elset=_Hot_faces_S6, internal, instance=Half_block-2, generate
   1,  1996,    5
*Elset, elset=_Hot_faces_S6, internal, instance=Half_block-3, generate
   1,  1996,    5
*Elset, elset=_Hot_faces_S6, internal, instance=Mortar-1, generate
   1,  1233,   308
*Surface, type=ELEMENT, name=Hot_faces
_Hot_faces_S1, S1
_Hot_faces_S5, S5
_Hot_faces_S2, S2
_Hot_faces_S4, S4
_Hot_faces_S6, S6
_Hot_faces_S3, S3
*Elset, elset=_Bottom_mortar_S3, internal, instance=Mortar-1
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 238,  239,  240,  241,  530,  531,  532,  533,  534,  535,  536,  537,  538,  539,  540,  541
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*Elset, elset=_Bottom_mortar_S4, internal, instance=Mortar-1, generate
 242,  1474,   308
*Elset, elset=_Bottom_mortar_S5, internal, instance=Mortar-1
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 259,  260,  261,  262,  263,  264,  265,  266,  267,  268,  269,  270,  271,  272,  273,  274
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*Surface, type=ELEMENT, name=Bottom_mortar
_Bottom_mortar_S3, S3
_Bottom_mortar_S4, S4
_Bottom_mortar_S5, S5
** Constraint: Constraint-1
*Tie, name=Constraint-1, adjust=yes, type=SURFACE TO SURFACE
Mortar, Surf-27(Blocks)
*End Assembly
*Amplitude, name=Furnace_temperature
      0.,     19.105,      30.,     20.02,      60.,    24.775,      90.,    35.005
    120.,     49.465,     150.,    65.685,     180.,    81.155,     210.,    93.655
    240.,      99.46,     270.,   101.155,     300.,    100.72,     330.,    98.895
    360.,      97.94,     390.,   100.515,     420.,    106.47,     450.,   114.815
    480.,    123.725,     510.,   131.575,     540.,   135.425,     570.,   136.585
    600.,    135.455,     630.,    137.26,     660.,   142.595,     690.,   150.115
    720.,     158.56,     750.,    164.16,     780.,   166.365,     810.,    169.54
    840.,     173.24,     870.,    177.66,     900.,   183.305,     930.,    189.19
    960.,    195.135,     990.,   196.815,    1020.,   197.895,    1050.,    201.31
   1080.,    207.035,    1110.,   214.105,    1140.,   221.135,    1170.,   226.625
   1200.,     226.92,    1230.,   226.065,    1260.,   230.205,    1290.,   237.015
   1320.,     245.53,    1350.,    255.56,    1380.,    265.92,    1410.,   271.265
   1440.,    272.295,    1470.,   271.025,    1500.,   271.305,    1530.,   272.375
   1560.,     277.88,    1590.,   284.845,    1620.,   292.185,    1650.,   299.415
   1680.,    303.845,    1710.,   305.665,    1740.,   308.205,    1770.,    310.57
   1800.,    312.725,    1830.,    319.74,    1860.,    327.44,    1890.,   333.785
   1920.,     339.58,    1950.,    340.84,    1980.,    346.67,    2010.,   352.125
   2040.,     357.02,    2070.,   362.435,    2100.,    365.41,    2130.,   369.775
   2160.,     374.07,    2190.,   379.915,    2220.,   384.935,    2250.,   389.915
   2280.,    395.525,    2310.,    399.28,    2340.,    398.29,    2370.,    390.65
   2400.,    385.445,    2430.,   384.255,    2460.,    385.59,    2490.,    388.84
   2520.,    391.955,    2550.,   393.135,    2580.,   393.315,    2610.,   392.905
   2640.,    391.945,    2670.,    390.53,    2700.,    388.71,    2730.,    387.26
   2760.,    388.955,    2790.,    390.72,    2820.,    392.31,    2850.,   391.695
   2880.,     390.98,    2910.,   391.075,    2940.,   392.755,    2970.,      393.
   3000.,    392.875,    3030.,    392.52,    3060.,    393.31,    3090.,   393.165
   3120.,    394.345,    3150.,    395.21,    3180.,   395.325,    3210.,    395.33
   3240.,     395.12,    3270.,   395.535,    3300.,    395.87,    3330.,    395.99
   3360.,    396.605,    3390.,   396.325,    3420.,    396.13,    3450.,    394.61
   3480.,      394.4,    3510.,   393.585,    3540.,   393.465,    3570.,     395.1
   3600.,     396.32,    3630.,   396.725,    3660.,   396.335,    3690.,   396.365
   3720.,     396.07,    3750.,    396.09,    3780.,     395.7,    3810.,   395.985
   3840.,    396.135,    3870.,    395.85,    3900.,    395.65,    3930.,    395.95
   3960.,    396.735,    3990.,   397.005,    4020.,    397.08,    4050.,   396.905
   4080.,     397.72,    4110.,   397.455,    4140.,     397.9,    4170.,   398.455
   4200.,     397.88,    4230.,   398.185,    4260.,   398.225,    4290.,   398.935
   4320.,     398.93,    4350.,   397.875,    4380.,   397.235,    4410.,    395.95
   4440.,     395.04,    4470.,    395.14,    4500.,     396.2,    4530.,    397.38
   4560.,     398.09,    4590.,   398.395,    4620.,    398.37,    4650.,    398.19
   4680.,    397.525,    4710.,   396.455,    4740.,    397.57,    4770.,   397.555
   4800.,    397.665,    4830.,      397.,    4860.,   398.445,    4890.,   398.535
   4920.,     398.84,    4950.,   398.215,    4980.,    398.88,    5010.,   398.925
   5040.,     398.48,    5070.,   398.925,    5100.,    398.42,    5130.,    398.89
   5160.,    398.815,    5190.,   399.375,    5220.,   399.405,    5250.,   400.015
   5280.,     400.03,    5310.,   400.865,    5340.,    400.87,    5370.,   400.345
   5400.,     400.17,    5430.,    399.56,    5460.,    398.71,    5490.,   398.075
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5520.,	397.495,	5550.,	398.455,	5580.,	400.01,	5610.,	400.24
5640.,	400.06,	5670.,	399.585,	5700.,	399.56,	5730.,	399.75
5760.,	399.175,	5790.,	398.83,	5820.,	399.12,	5850.,	399.905
5880.,	400.465,	5910.,	400.3,	5940.,	399.45,	5970.,	400.135
6000.,	399.715,	6030.,	399.79,	6060.,	400.035,	6090.,	400.255
6120.,	401.025,	6150.,	401.98,	6180.,	401.74,	6210.,	401.85
6240.,	401.925,	6270.,	402.14,	6300.,	401.47,	6330.,	400.915
6360.,	399.865,	6390.,	398.615,	6420.,	398.665,	6450.,	399.165
6480.,	399.425,	6510.,	401.26,	6540.,	401.535,	6570.,	401.12
6600.,	400.87,	6630.,	399.475,	6660.,	400.12,	6690.,	400.65
6720.,	400.615,	6750.,	400.74,	6780.,	400.735,	6810.,	400.07
6840.,	400.735,	6870.,	400.665,	6900.,	400.825,	6930.,	400.97
6960.,	400.64,	6990.,	400.61,	7020.,	401.355,	7050.,	401.64
7080.,	401.895,	7110.,	401.59,	7140.,	401.205,	7170.,	401.305
7200.,	401.155,	7230.,	401.035,	7260.,	401.03,	7290.,	400.93
7320.,	401.03,	7350.,	401.625,	7380.,	401.675,	7410.,	402.08
7440.,	402.06,	7470.,	402.76,	7500.,	403.11,	7530.,	403.37
7560.,	403.92,	7590.,	404.125,	7620.,	403.29,	7650.,	401.665
7680.,	399.86,	7710.,	398.7,	7740.,	398.68,	7770.,	399.27
7800.,	400.335,	7830.,	400.41,	7860.,	401.76,	7890.,	402.925
7920.,	403.21,	7950.,	402.88,	7980.,	402.415,	8010.,	401.255
8040.,	400.685,	8070.,	401.11,	8100.,	400.005,	8130.,	398.275
8160.,	396.6,	8190.,	396.135,	8220.,	398.155,	8250.,	404.98
8280.,	412.83,	8310.,	414.405,	8340.,	412.24,	8370.,	409.615
8400.,	407.035,	8430.,	404.26,	8460.,	401.815,	8490.,	399.38
8520.,	396.915,	8550.,	394.77,	8580.,	395.295,	8610.,	397.755
8640.,	400.585,	8670.,	402.835,	8700.,	403.57,	8730.,	403.365
8760.,	402.31,	8790.,	401.29,	8820.,	400.105,	8850.,	399.825
8880.,	399.595,	8910.,	400.98,	8940.,	401.425,	8970.,	400.95
9000.,	400.975,	9030.,	400.545,	9060.,	400.125,	9090.,	399.88
9120.,	401.3,	9150.,	401.81,	9180.,	402.01,	9210.,	401.775
9240.,	401.67,	9270.,	401.18,	9300.,	400.58,	9330.,	400.61
9360.,	400.37,	9390.,	400.68,	9420.,	401.37,	9450.,	401.265
9480.,	401.59,	9510.,	401.91,	9540.,	401.83,	9570.,	401.67
9600.,	402.08,	9630.,	401.98,	9660.,	401.6,	9690.,	401.85
9720.,	402.085,	9750.,	402.495,	9780.,	402.735,	9810.,	403.01
9840.,	402.675,	9870.,	403.,	9900.,	403.095,	9930.,	403.115
9960.,	403.195,	9990.,	403.485,	10020.,	403.62,	10050.,	403.91
10080.,	404.135,	10110.,	404.455,	10140.,	404.325,	10170.,	404.47
10200.,	404.455,	10230.,	404.275,	10260.,	404.35,	10290.,	404.365
10320.,	405.03,	10350.,	404.79,	10380.,	403.935,	10410.,	402.22
10440.,	400.19,	10470.,	398.595,	10500.,	398.4,	10530.,	399.545
10560.,	400.52,	10590.,	401.605,	10620.,	402.75,	10650.,	403.27
10680.,	402.52,	10710.,	401.47,	10740.,	400.715,	10770.,	400.235
10800.,	400.63,	10830.,	402.445,	10860.,	402.99,	10890.,	402.915
10920.,	402.185,	10950.,	401.645,	10980.,	400.76,	11010.,	399.53
11040.,	397.49,	11070.,	396.645,	11100.,	398.55,	11130.,	404.235
11160.,	412.21,	11190.,	414.925,	11220.,	413.78,	11250.,	411.36
11280.,	408.69,	11310.,	406.845,	11340.,	404.835,	11370.,	402.62
11400.,	400.705,	11430.,	398.945,	11460.,	396.96,	11490.,	395.615
11520.,	395.8,	11550.,	398.26,	11580.,	401.05,	11610.,	402.88
11640.,	402.925,	11670.,	402.375,	11700.,	401.795,	11730.,	401.095
11760.,	400.56,	11790.,	399.63,	11820.,	399.2,	11850.,	399.67
11880.,	400.465,	11910.,	400.615,	11940.,	400.42,	11970.,	399.985
12000.,	400.65,	12030.,	401.16,	12060.,	400.99,	12090.,	400.23
12120.,	400.105,	12150.,	400.135,	12180.,	399.7,	12210.,	399.845
12240.,	400.805,	12270.,	401.535,	12300.,	401.63,	12330.,	401.805
12360.,	401.95,	12390.,	402.23,	12420.,	402.45,	12450.,	402.505
12480.,	402.6,	12510.,	402.18,	12540.,	401.85,	12570.,	401.1
12600.,	400.375,	12630.,	399.765,	12660.,	399.055,	12690.,	399.72

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     12720.,      400.52,      12750.,      400.87,      12780.,     401.205,      12810.,      401.03
     12840.,     400.675,      12870.,      400.24,      12900.,      400.19,      12930.,     399.975
     12960.,     399.805,      12990.,      399.92,      13020.,     400.175,      13050.,      400.26
     13080.,     400.045,      13110.,      399.74,      13140.,      399.82,      13170.,     400.165
     13200.,      400.78,      13230.,      401.08,      13260.,      401.63,      13290.,     401.735
     13320.,       401.7,      13350.,      401.82,      13380.,     402.065,      13410.,      401.94
     13440.,       402.1,      13470.,     402.175,      13500.,      402.21,      13530.,     402.465
     13560.,     402.445,      13590.,     402.265,      13620.,       402.2,      13650.,      401.78
     13680.,     401.225,      13710.,      400.58,      13740.,      399.78,      13770.,     399.685
     13800.,     400.515,      13830.,     401.385,      13860.,     401.615,      13890.,     401.745
     13920.,     401.395,      13950.,      401.16,      13980.,      400.82,      14010.,       400.6
     14040.,      400.51,      14070.,      400.18,      14100.,      400.28,      14130.,     400.545
     14160.,      401.46,      14190.,      401.68,      14220.,     401.395,      14250.,       401.3
     14280.,      401.16,      14310.,     400.895,      14340.,      400.38,      14370.,      400.52
     14400.,       400.1,      14430.,     401.135,      14460.,      401.33,      14490.,     401.215
     14520.,     400.885,      14550.,      400.59,      14580.,     400.365,      14610.,     400.255
     14640.,      401.07,      14670.,     401.035,      14700.,      401.43,      14730.,      401.66
     14760.,      401.86,      14790.,      402.16,      14820.,     402.155,      14850.,      402.19
     14880.,      402.71,      14910.,      402.68,      14940.,      403.02,      14970.,     402.735
     15000.,     401.715,      15030.,      400.89,      15060.,      399.07,      15090.,      397.85
     15120.,     398.195,      15150.,     398.795,      15180.,      399.85,      15210.,      400.79
     15240.,     401.595,      15270.,     402.785,      15300.,      402.44,      15330.,      401.64
     15360.,      401.33,      15390.,     400.755,      15420.,     400.235,      15450.,      399.89
     15480.,       400.3,      15510.,     401.675,      15540.,     402.365,      15570.,       402.3
     15600.,      402.12,      15630.,      401.88,      15660.,      401.64,      15690.,      401.55
     15720.,      401.36,      15750.,     400.995,      15780.,     400.915,      15810.,      400.84
     15840.,     400.565,      15870.,      400.61,      15900.,     400.865,      15930.,     400.735
     15960.,      400.93,      15990.,      401.72
**
** MATERIALS
**
*Material, name="Lightweight concrete"
*Conductivity
 0.33,400.
*Density
1400.,
*Latent Heat
48000.,100.,119.
*Specific Heat
700.,400.
*Material, name=Mortar_properties
*Conductivity
 1.4,400.
*Density
1900.,
*Latent Heat
89000.,100.,115.
*Specific Heat
5000.,400.
**
** INTERACTION PROPERTIES
**
*Film Property, name=Cold_face
4., 400.
*Film Property, name=Hot_face
25., 400.
**
** PHYSICAL CONSTANTS
**
*Physical Constants, absolute zero=-273., stefan boltzmann=5.67e-08
```

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**
** PREDEFINED FIELDS
**
** Name: Predefined Field-1   Type: Temperature
*Initial Conditions, type=TEMPERATURE
_PickedSet2365, 19.
** ----------------------------------------------------------------
**
** STEP: Heat transfer
**
*Step, name="Heat transfer", inc=10000
*Heat Transfer, end=PERIOD, deltmx=10.
0.1, 15990., 0.001, 15990.,
**
** INTERACTIONS
**
** Interaction: Bottom_cold_mortar
*Sfilm, amplitude=Furnace_temperature
Bottom_mortar, F, 1., Cold_face
** Interaction: External_hot_faces_specimen
*Sfilm, amplitude=Furnace_temperature
Hot_faces, F, 1., Hot_face
** Interaction: Internal_cold_block_faces
*Sfilm, amplitude=Furnace_temperature
Surf-27(Blocks), F, 1., Cold_face
** Interaction: Internal_cold_mortar_faces
*Sfilm, amplitude=Furnace_temperature
Mortar, F, 1., Cold_face
** Interaction: Radiation_Furnace_temperature
*Sradiate, amplitude=Furnace_temperature
Hot_faces, R, 1., 0.7
** Interaction: Radiation_bottom_mortar
*Sradiate
Bottom_mortar, R, 20., 0.7
** Interaction: Radiation_cold_top_mortar
*Sradiate
Top_mortar, R, 20., 0.7
** Interaction: Top_cold_mortar
*Sfilm, amplitude=Furnace_temperature
Top_mortar, F, 1., Cold_face
**
** OUTPUT REQUESTS
**
*Restart, write, frequency=0
**
** FIELD OUTPUT: F-Output-1
**
*Output, field, variable=PRESELECT
*Output, history, frequency=0
*End Step
```

Thermal analysis data of wallettes at 600ºC

```
*Elset, elset=_Hot_faces_S2, internal, instance=Half_block-1, generate
  1, 100,   1
*Elset, elset=_Hot_faces_S2, internal, instance=Half_block-3, generate
  1, 100,   1
*Elset, elset=_Hot_faces_S2, internal, instance=Mortar-1, generate
 1233,  1540,    1
*Elset, elset=_Hot_faces_S4, internal, instance=Half_block-1, generate
    5,  2000,     5
*Elset, elset=_Hot_faces_S4, internal, instance=Half_block-2, generate
    5,  2000,     5
*Elset, elset=_Hot_faces_S4, internal, instance=Half_block-3, generate
    5,  2000,     5
*Elset, elset=_Hot_faces_S4, internal, instance=Mortar-1
   62,   97,  164,  204,  241,  283,  306,  370,  405,  472,  512,  549,  591,  614,  678,  713
  780,  820,  857,  899,  922,  986, 1021, 1088, 1128, 1165, 1207, 1230, 1294, 1329, 1396, 1436
 1473, 1515, 1538
*Elset, elset=_Hot_faces_S6, internal, instance=Half_block-1, generate
    1,  1996,     5
*Elset, elset=_Hot_faces_S6, internal, instance=Half_block-2, generate
    1,  1996,     5
*Elset, elset=_Hot_faces_S6, internal, instance=Half_block-3, generate
    1,  1996,     5
*Elset, elset=_Hot_faces_S6, internal, instance=Mortar-1, generate
    1,  1233,   308
*Surface, type=ELEMENT, name=Hot_faces
_Hot_faces_S1, S1
_Hot_faces_S5, S5
_Hot_faces_S2, S2
_Hot_faces_S4, S4
_Hot_faces_S6, S6
_Hot_faces_S3, S3
*Elset, elset=_Bottom_mortar_S3, internal, instance=Mortar-1
  222,  223,  224,  225,  226,  227,  228,  229,  230,  231,  232,  233,  234,  235,  236,  237
  238,  239,  240,  241,  530,  531,  532,  533,  534,  535,  536,  537,  538,  539,  540,  541
  542,  543,  544,  545,  546,  547,  548,  549,  838,  839,  840,  841,  842,  843,  844,  845
  846,  847,  848,  849,  850,  851,  852,  853,  854,  855,  856,  857, 1146, 1147, 1148, 1149
 1150, 1151, 1152, 1153, 1154, 1155, 1156, 1157, 1158, 1159, 1160, 1161, 1162, 1163, 1164,
1165
 1454, 1455, 1456, 1457, 1458, 1459, 1460, 1461, 1462, 1463, 1464, 1465, 1466, 1467, 1468,
1469
 1470, 1471, 1472, 1473
*Elset, elset=_Bottom_mortar_S4, internal, instance=Mortar-1, generate
  242,  1474,   308
*Elset, elset=_Bottom_mortar_S5, internal, instance=Mortar-1
  243,  244,  245,  246,  247,  248,  249,  250,  251,  252,  253,  254,  255,  256,  257,  258
  259,  260,  261,  262,  263,  264,  265,  266,  267,  268,  269,  270,  271,  272,  273,  274
  275,  276,  277,  278,  279,  280,  281,  282,  283,  551,  552,  553,  554,  555,  556,  557
  558,  559,  560,  561,  562,  563,  564,  565,  566,  567,  568,  569,  570,  571,  572,  573
  574,  575,  576,  577,  578,  579,  580,  581,  582,  583,  584,  585,  586,  587,  588,  589
  590,  591,  859,  860,  861,  862,  863,  864,  865,  866,  867,  868,  869,  870,  871,  872
  873,  874,  875,  876,  877,  878,  879,  880,  881,  882,  883,  884,  885,  886,  887,  888
  889,  890,  891,  892,  893,  894,  895,  896,  897,  898,  899, 1167, 1168, 1169, 1170, 1171
 1172, 1173, 1174, 1175, 1176, 1177, 1178, 1179, 1180, 1181, 1182, 1183, 1184, 1185, 1186,
1187
 1188, 1189, 1190, 1191, 1192, 1193, 1194, 1195, 1196, 1197, 1198, 1199, 1200, 1201, 1202,
1203
 1204, 1205, 1206, 1207, 1475, 1476, 1477, 1478, 1479, 1480, 1481, 1482, 1483, 1484, 1485,
1486
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 1487, 1488, 1489, 1490, 1491, 1492, 1493, 1494, 1495, 1496, 1497, 1498, 1499, 1500, 1501,
1502
 1503, 1504, 1505, 1506, 1507, 1508, 1509, 1510, 1511, 1512, 1513, 1514, 1515
*Surface, type=ELEMENT, name=Bottom_mortar
_Bottom_mortar_S3, S3
_Bottom_mortar_S4, S4
_Bottom_mortar_S5, S5
** Constraint: Constraint-1
*Tie, name=Constraint-1, adjust=yes, type=SURFACE TO SURFACE
Mortar, Surf-27(Blocks)
*End Assembly
*Amplitude, name=Furnace_temperature
          0.,      20.94,        30.,      20.95,        60.,      21.06,        90.,      21.99
        120.,     24.745,       150.,     32.815,       180.,     46.585,       210.,     63.185
        240.,     80.305,       270.,      93.98,       300.,    103.685,       330.,     109.67
        360.,    111.935,       390.,     111.15,       420.,    110.225,       450.,    111.045
        480.,     113.09,       510.,     116.42,       540.,     121.61,       570.,     127.16
        600.,     133.53,       630.,     139.86,       660.,    146.005,       690.,       151.
        720.,     155.21,       750.,    158.515,       780.,     161.68,       810.,     164.96
        840.,     168.29,       870.,     172.61,       900.,    176.975,       930.,     181.86
        960.,    187.215,       990.,    192.775,      1020.,    198.105,      1050.,     202.92
       1080.,     206.05,      1110.,    210.205,      1140.,     215.11,      1170.,     221.37
       1200.,      226.7,      1230.,    231.235,      1260.,    236.405,      1290.,    240.245
       1320.,    243.335,      1350.,    247.355,      1380.,     258.09,      1410.,    269.825
       1440.,     275.62,      1470.,     276.37,      1500.,    275.055,      1530.,    276.115
       1560.,    280.045,      1590.,     286.13,      1620.,    293.685,      1650.,      301.9
       1680.,    307.655,      1710.,    310.645,      1740.,    312.595,      1770.,    316.115
       1800.,     321.36,      1830.,     326.76,      1860.,    331.285,      1890.,     336.75
       1920.,    341.025,      1950.,    346.315,      1980.,    351.745,      2010.,    356.915
       2040.,    362.095,      2070.,     366.92,      2100.,     371.01,      2130.,     375.47
       2160.,    380.015,      2190.,    384.715,      2220.,     390.08,      2250.,    394.255
       2280.,     399.45,      2310.,    404.195,      2340.,     409.37,      2370.,    413.495
       2400.,     418.93,      2430.,     423.31,      2460.,    428.415,      2490.,     433.26
       2520.,    437.555,      2550.,    442.665,      2580.,    447.145,      2610.,    452.855
       2640.,     457.48,      2670.,     462.27,      2700.,       467.,      2730.,    471.015
       2760.,     474.43,      2790.,    478.265,      2820.,     483.57,      2850.,    487.085
       2880.,     491.65,      2910.,    494.495,      2940.,     498.14,      2970.,    502.965
       3000.,    508.065,      3030.,    511.005,      3060.,     514.94,      3090.,     518.26
       3120.,    522.345,      3150.,      526.5,      3180.,    528.775,      3210.,    531.815
       3240.,    536.065,      3270.,    540.065,      3300.,     542.78,      3330.,     546.01
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       3480.,    562.155,      3510.,     566.13,      3540.,    569.875,      3570.,    572.395
       3600.,    575.115,      3630.,     576.98,      3660.,     580.54,      3690.,    583.455
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       3960.,     594.26,      3990.,    596.335,      4020.,     597.74,      4050.,     593.06
       4080.,    593.135,      4110.,     594.96,      4140.,    596.025,      4170.,     596.93
       4200.,     597.96,      4230.,     597.26,      4260.,     595.79,      4290.,     596.21
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       5640.,    601.285,      5670.,    601.305,      5700.,     601.31,      5730.,    601.705
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6000.,	600.165,	6030.,	599.975,	6060.,	599.93,	6090.,	599.79
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8040.,	602.025,	8070.,	602.07,	8100.,	602.615,	8130.,	602.775
8160.,	603.08,	8190.,	603.37,	8220.,	603.4,	8250.,	602.675
8280.,	601.81,	8310.,	601.96,	8340.,	602.395,	8370.,	602.41
8400.,	601.915,	8430.,	601.57,	8460.,	602.175,	8490.,	602.355
8520.,	602.785,	8550.,	602.61,	8580.,	602.275,	8610.,	602.58
8640.,	602.86,	8670.,	602.795,	8700.,	602.76,	8730.,	602.015
8760.,	602.6,	8790.,	602.91,	8820.,	602.615,	8850.,	603.115
8880.,	602.715,	8910.,	602.51,	8940.,	603.35,	8970.,	603.19
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9480.,	601.605,	9510.,	601.85,	9540.,	601.85,	9570.,	602.135
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11880.,	603.16,	11910.,	603.525,	11940.,	603.275,	11970.,	603.275
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    15480.,    603.625,    15510.,    603.55,    15540.,    603.595,    15570.,    603.5
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    15960.,    603.935
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** MATERIALS
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*Material, name="Lightweight concrete"
*Conductivity
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*Density
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*Latent Heat
48000.,107.,149.
*Specific Heat
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*Material, name=Mortar_properties
*Conductivity
 1.4,600.
*Density
1900.,
*Latent Heat
89000.,100.,113.
*Specific Heat
4000.,600.
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** INTERACTION PROPERTIES
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*Film Property, name=Cold_face
4., 600.
*Film Property, name=Hot_face
25., 600.
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** PHYSICAL CONSTANTS
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*Physical Constants, absolute zero=-273., stefan boltzmann=5.67e-08
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** PREDEFINED FIELDS
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** Name: Predefined Field-1   Type: Temperature
*Initial Conditions, type=TEMPERATURE
_PickedSet2365, 19.
** ----------------------------------------------------------------
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** STEP: Heat transfer
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*Step, name="Heat transfer", inc=10000
*Heat Transfer, end=PERIOD, deltmx=10.
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** INTERACTIONS
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** Interaction: Bottom_cold_mortar
*Sfilm, amplitude=Furnace_temperature
Bottom_mortar, F, 1., Cold_face
** Interaction: External_hot_faces_specimen
*Sfilm, amplitude=Furnace_temperature
Hot_faces, F, 1., Hot_face
** Interaction: Internal_cold_block_faces
*Sfilm, amplitude=Furnace_temperature
Surf-27(Blocks), F, 1., Cold_face
** Interaction: Internal_cold_mortar_faces
*Sfilm, amplitude=Furnace_temperature
Mortar, F, 1., Cold_face
** Interaction: Radiation_Furnace_temperature
*Sradiate, amplitude=Furnace_temperature
Hot_faces, R, 1., 0.7
** Interaction: Radiation_bottom_mortar
*Sradiate
Bottom_mortar, R, 20., 0.7
** Interaction: Radiation_cold_top_mortar
*Sradiate
Top_mortar, R, 20., 0.7
** Interaction: Top_cold_mortar
*Sfilm, amplitude=Furnace_temperature
Top_mortar, F, 1., Cold_face
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** OUTPUT REQUESTS
**
*Restart, write, frequency=0
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** FIELD OUTPUT: F-Output-1
**
*Output, field, variable=PRESELECT
*Output, history, frequency=0
*End Step
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Thermal analysis data of wallettes at 700ºC

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*Elset, elset=_Hot_faces_S2, internal, instance=Half_block-1, generate
  1, 100,   1
*Elset, elset=_Hot_faces_S2, internal, instance=Half_block-3, generate
  1, 100,   1
*Elset, elset=_Hot_faces_S2, internal, instance=Mortar-1, generate
 1233,  1540,    1
*Elset, elset=_Hot_faces_S4, internal, instance=Half_block-1, generate
   5,  2000,    5
*Elset, elset=_Hot_faces_S4, internal, instance=Half_block-2, generate
   5,  2000,    5
*Elset, elset=_Hot_faces_S4, internal, instance=Half_block-3, generate
   5,  2000,    5
*Elset, elset=_Hot_faces_S4, internal, instance=Mortar-1
  62,   97,  164,  204,  241,  283,  306,  370,  405,  472,  512,  549,  591,  614,  678,  713
  780,  820,  857,  899,  922,  986, 1021, 1088, 1128, 1165, 1207, 1230, 1294, 1329, 1396, 1436
 1473, 1515, 1538
*Elset, elset=_Hot_faces_S6, internal, instance=Half_block-1, generate
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*Elset, elset=_Hot_faces_S6, internal, instance=Half_block-2, generate
   1,  1996,    5
*Elset, elset=_Hot_faces_S6, internal, instance=Half_block-3, generate
   1,  1996,    5
*Elset, elset=_Hot_faces_S6, internal, instance=Mortar-1, generate
   1,  1233,   308
*Surface, type=ELEMENT, name=Hot_faces
_Hot_faces_S1, S1
_Hot_faces_S5, S5
_Hot_faces_S2, S2
_Hot_faces_S4, S4
_Hot_faces_S6, S6
_Hot_faces_S3, S3
*Elset, elset=_Bottom_mortar_S3, internal, instance=Mortar-1
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  238,  239,  240,  241,  530,  531,  532,  533,  534,  535,  536,  537,  538,  539,  540,  541
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1469
 1470, 1471, 1472, 1473
*Elset, elset=_Bottom_mortar_S4, internal, instance=Mortar-1, generate
  242,  1474,   308
*Elset, elset=_Bottom_mortar_S5, internal, instance=Mortar-1
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1486
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1487, 1488, 1489, 1490, 1491, 1492, 1493, 1494, 1495, 1496, 1497, 1498, 1499, 1500, 1501, 1502
1503, 1504, 1505, 1506, 1507, 1508, 1509, 1510, 1511, 1512, 1513, 1514, 1515
*Surface, type=ELEMENT, name=Bottom_mortar
_Bottom_mortar_S3, S3
_Bottom_mortar_S4, S4
_Bottom_mortar_S5, S5
** Constraint: Constraint-1
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Mortar, Surf-27(Blocks)
*End Assembly
*Amplitude, name=Furnace_temperature
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360., 92.15, 390., 96.55, 420., 104.88, 450., 113.8
480., 120.94, 510., 126.41, 540., 127.21, 570., 125.45
600., 127.66, 630., 134.11, 660., 141.88, 690., 150.11
720., 153.56, 750., 152.94, 780., 157.4, 810., 164.1
840., 171.04, 870., 173.51, 900., 174.94, 930., 179.86
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1920., 326.54, 1950., 330.42, 1980., 335.68, 2010., 338.29
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5640., 694.5, 5670., 696.8, 5700., 696.3, 5730., 695.4

5760.,	694.8,	5790.,	694.9,	5820.,	695.7,	5850.,	696.
5880.,	696.5,	5910.,	696.2,	5940.,	696.,	5970.,	696.7
6000.,	696.3,	6030.,	696.3,	6060.,	697.7,	6090.,	697.7
6120.,	698.4,	6150.,	698.4,	6180.,	697.9,	6210.,	699.2
6240.,	697.3,	6270.,	695.9,	6300.,	696.,	6330.,	696.5
6360.,	697.1,	6390.,	697.6,	6420.,	698.2,	6450.,	697.5
6480.,	697.8,	6510.,	697.8,	6540.,	698.5,	6570.,	698.4
6600.,	698.,	6630.,	699.2,	6660.,	699.,	6690.,	699.4
6720.,	699.6,	6750.,	699.5,	6780.,	698.7,	6810.,	698.7
6840.,	698.6,	6870.,	697.6,	6900.,	698.7,	6930.,	699.
6960.,	698.6,	6990.,	698.2,	7020.,	697.9,	7050.,	698.9
7080.,	699.4,	7110.,	699.6,	7140.,	699.,	7170.,	698.8
7200.,	698.9,	7230.,	699.,	7260.,	699.6,	7290.,	699.1
7320.,	699.1,	7350.,	699.4,	7380.,	699.7,	7410.,	699.6
7440.,	699.7,	7470.,	700.1,	7500.,	700.4,	7530.,	700.5
7560.,	701.2,	7590.,	700.7,	7620.,	701.3,	7650.,	699.8
7680.,	699.2,	7710.,	699.,	7740.,	699.4,	7770.,	699.
7800.,	699.5,	7830.,	699.5,	7860.,	699.3,	7890.,	699.5
7920.,	699.3,	7950.,	699.9,	7980.,	700.,	8010.,	700.
8040.,	700.2,	8070.,	700.4,	8100.,	701.,	8130.,	701.3
8160.,	701.2,	8190.,	701.4,	8220.,	700.5,	8250.,	700.6
8280.,	700.1,	8310.,	700.,	8340.,	700.,	8370.,	700.4
8400.,	700.8,	8430.,	700.7,	8460.,	700.5,	8490.,	700.5
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8640.,	700.7,	8670.,	701.5,	8700.,	701.3,	8730.,	701.7
8760.,	701.4,	8790.,	700.7,	8820.,	700.4,	8850.,	700.3
8880.,	700.2,	8910.,	700.1,	8940.,	700.,	8970.,	700.6
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9120.,	700.6,	9150.,	700.8,	9180.,	700.3,	9210.,	700.4
9240.,	700.9,	9270.,	700.8,	9300.,	700.9,	9330.,	701.1
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9480.,	701.6,	9510.,	701.6,	9540.,	701.9,	9570.,	702.3
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10200.,	700.6,	10230.,	700.7,	10260.,	700.9,	10290.,	701.
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10680.,	702.1,	10710.,	702.6,	10740.,	702.5,	10770.,	702.5
10800.,	702.6,	10830.,	702.5,	10860.,	702.6,	10890.,	702.3
10920.,	701.8,	10950.,	701.8,	10980.,	701.6,	11010.,	701.6
11040.,	701.5,	11070.,	701.3,	11100.,	700.9,	11130.,	701.2
11160.,	701.3,	11190.,	701.4,	11220.,	700.9,	11250.,	700.9
11280.,	701.2,	11310.,	701.9,	11340.,	701.3,	11370.,	701.1
11400.,	701.3,	11430.,	701.3,	11460.,	701.4,	11490.,	701.5
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11640.,	703.4,	11670.,	702.,	11700.,	702.1,	11730.,	702.4
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11880.,	702.8,	11910.,	702.6,	11940.,	702.7,	11970.,	702.5
12000.,	702.8,	12030.,	703.2,	12060.,	703.1,	12090.,	702.8
12120.,	703.1,	12150.,	703.2,	12180.,	703.6,	12210.,	703.6
12240.,	703.3,	12270.,	702.1,	12300.,	702.2,	12330.,	701.9
12360.,	701.8,	12390.,	701.4,	12420.,	701.8,	12450.,	702.2
12480.,	702.3,	12510.,	701.9,	12540.,	701.6,	12570.,	701.6
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12720.,	702.3,	12750.,	702.4,	12780.,	702.9,	12810.,	702.9
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17400., 703.8, 17430., 703.8, 17460., 703.4, 17490., 703.4
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17880., 705.4, 17910., 705., 17940., 704.6, 17970., 704.6
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18240., 703.4, 18270., 703.6, 18300., 704., 18330., 703.8
18360., 703.5, 18390., 703.4, 18420., 703.9, 18450., 703.9
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18960., 703.5, 18990., 703.8, 19020., 704., 19050., 703.9
19080., 703.7, 19110., 703.7, 19140., 703.7, 19170., 703.9
19200., 704., 19230., 703.8, 19260., 703.8, 19290., 703.8
19320., 703.9, 19350., 703.7, 19380., 703.6, 19410., 704.
19440., 704., 19470., 703.9, 19500., 703.9, 19530., 703.7
19560., 703.8, 19590., 703.9, 19620., 703.9
**
** MATERIALS
**
*Material, name="Lightweight concrete"
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*Conductivity
 0.32,700.
*Density
1400.,
*Latent Heat
48000.,104.,145.
*Specific Heat
750.,700.
*Material, name=Mortar_properties
*Conductivity
 1.4,700.
*Density
1900.,
*Latent Heat
89000.,100.,113.
*Specific Heat
4000.,700.
**
** INTERACTION PROPERTIES
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*Film Property, name=Cold_face
4., 700.
*Film Property, name=Hot_face
25., 700.
**
** PHYSICAL CONSTANTS
**
*Physical Constants, absolute zero=-273., stefan boltzmann=5.67e-08
**
** PREDEFINED FIELDS
**
** Name: Predefined Field-1   Type: Temperature
*Initial Conditions, type=TEMPERATURE
_PickedSet2365, 19.
** ----------------------------------------------------------------
**
** STEP: Heat transfer
**
*Step, name="Heat transfer", inc=10000
*Heat Transfer, end=PERIOD, deltmx=10.
1., 19620., 0.001, 19620.,
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** INTERACTIONS
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** Interaction: Bottom_cold_mortar
*Sfilm, amplitude=Furnace_temperature
Bottom_mortar, F, 1., Cold_face
** Interaction: External_hot_faces_specimen
*Sfilm, amplitude=Furnace_temperature
Hot_faces, F, 1., Hot_face
** Interaction: Internal_cold_block_faces
*Sfilm, amplitude=Furnace_temperature
Surf-27(Blocks), F, 1., Cold_face
** Interaction: Internal_cold_mortar_faces
*Sfilm, amplitude=Furnace_temperature
Mortar, F, 1., Cold_face
** Interaction: Radiation_Furnace_temperature
*Sradiate, amplitude=Furnace_temperature
Hot_faces, R, 1., 0.7
** Interaction: Radiation_bottom_mortar
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*Sradiate
Bottom_mortar, R, 20., 0.7
** Interaction: Radiation_cold_top_mortar
*Sradiate
Top_mortar, R, 20., 0.7
** Interaction: Top_cold_mortar
*Sfilm, amplitude=Furnace_temperature
Top_mortar, F, 1., Cold_face
**
** OUTPUT REQUESTS
**
*Restart, write, frequency=0
**
** FIELD OUTPUT: F-Output-1
**
*Output, field, variable=PRESELECT
*Output, history, frequency=0
*End Step
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Thermal analysis data of wallettes at 800ºC

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*Elset, elset=_Hot_faces_S2, internal, instance=Half_block-1, generate
 1, 100,   1
*Elset, elset=_Hot_faces_S2, internal, instance=Half_block-3, generate
 1, 100,   1
*Elset, elset=_Hot_faces_S2, internal, instance=Mortar-1, generate
 1233,  1540,    1
*Elset, elset=_Hot_faces_S4, internal, instance=Half_block-1, generate
   5,  2000,    5
*Elset, elset=_Hot_faces_S4, internal, instance=Half_block-2, generate
   5,  2000,    5
*Elset, elset=_Hot_faces_S4, internal, instance=Half_block-3, generate
   5,  2000,    5
*Elset, elset=_Hot_faces_S4, internal, instance=Mortar-1
  62,   97,  164,  204,  241,  283,  306,  370,  405,  472,  512,  549,  591,  614,  678,  713
 780,  820,  857,  899,  922,  986, 1021, 1088, 1128, 1165, 1207, 1230, 1294, 1329, 1396, 1436
 1473, 1515, 1538
*Elset, elset=_Hot_faces_S6, internal, instance=Half_block-1, generate
   1,  1996,    5
*Elset, elset=_Hot_faces_S6, internal, instance=Half_block-2, generate
   1,  1996,    5
*Elset, elset=_Hot_faces_S6, internal, instance=Half_block-3, generate
   1,  1996,    5
*Elset, elset=_Hot_faces_S6, internal, instance=Mortar-1, generate
   1,  1233,   308
*Surface, type=ELEMENT, name=Hot_faces
_Hot_faces_S1, S1
_Hot_faces_S5, S5
_Hot_faces_S2, S2
_Hot_faces_S4, S4
_Hot_faces_S6, S6
_Hot_faces_S3, S3
*Elset, elset=_Bottom_mortar_S3, internal, instance=Mortar-1
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 238,  239,  240,  241,  530,  531,  532,  533,  534,  535,  536,  537,  538,  539,  540,  541
 542,  543,  544,  545,  546,  547,  548,  549,  838,  839,  840,  841,  842,  843,  844,  845
 846,  847,  848,  849,  850,  851,  852,  853,  854,  855,  856,  857, 1146, 1147, 1148, 1149
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1469
 1470, 1471, 1472, 1473
*Elset, elset=_Bottom_mortar_S4, internal, instance=Mortar-1, generate
 242,  1474,   308
*Elset, elset=_Bottom_mortar_S5, internal, instance=Mortar-1
 243,  244,  245,  246,  247,  248,  249,  250,  251,  252,  253,  254,  255,  256,  257,  258
 259,  260,  261,  262,  263,  264,  265,  266,  267,  268,  269,  270,  271,  272,  273,  274
 275,  276,  277,  278,  279,  280,  281,  282,  283,  551,  552,  553,  554,  555,  556,  557
 558,  559,  560,  561,  562,  563,  564,  565,  566,  567,  568,  569,  570,  571,  572,  573
 574,  575,  576,  577,  578,  579,  580,  581,  582,  583,  584,  585,  586,  587,  588,  589
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1486
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1502
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*Surface, type=ELEMENT, name=Bottom_mortar
_Bottom_mortar_S3, S3
_Bottom_mortar_S4, S4
_Bottom_mortar_S5, S5
** Constraint: Constraint-1
*Tie, name=Constraint-1, adjust=yes, type=SURFACE TO SURFACE
Mortar, Surf-27(Blocks)
*End Assembly
*Amplitude, name=Furnace_temperature
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    240.,     73.66,      270.,     75.36,      300.,     75.41,      330.,     73.99
    360.,     75.23,      390.,     79.21,      420.,     86.64,      450.,      95.9
    480.,    103.24,      510.,    107.57,      540.,     107.2,      570.,    106.67
    600.,    107.56,      630.,    111.12,      660.,    117.56,      690.,    125.04
    720.,    131.39,      750.,     134.1,      780.,    133.91,      810.,    135.19
    840.,    140.75,      870.,    148.63,      900.,    155.29,      930.,    160.21
    960.,    160.63,      990.,    163.98,     1020.,    168.97,     1050.,    172.88
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   1200.,    197.94,     1230.,      198.,     1260.,     200.2,     1290.,    205.17
   1320.,    211.11,     1350.,    216.94,     1380.,    226.53,     1410.,     235.6
   1440.,    239.46,     1470.,    239.71,     1500.,    238.76,     1530.,    239.81
   1560.,    244.83,     1590.,    252.48,     1620.,      260.,     1650.,    265.18
   1680.,    269.49,     1710.,    275.52,     1740.,    278.27,     1770.,    282.81
   1800.,    286.74,     1830.,    289.26,     1860.,    293.91,     1890.,    301.52
   1920.,    307.03,     1950.,    313.21,     1980.,    318.32,     2010.,     323.3
   2040.,    325.58,     2070.,    331.27,     2100.,    338.02,     2130.,    341.51
   2160.,    345.09,     2190.,    353.53,     2220.,    355.25,     2250.,    360.37
   2280.,    366.66,     2310.,    367.41,     2340.,    371.94,     2370.,    374.18
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   2640.,    417.88,     2670.,     427.3,     2700.,    432.45,     2730.,    437.41
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   2880.,    460.77,     2910.,    465.62,     2940.,     468.3,     2970.,    473.76
   3000.,    480.31,     3030.,    483.56,     3060.,    488.05,     3090.,    491.04
   3120.,    492.67,     3150.,     498.7,     3180.,    502.18,     3210.,    504.59
   3240.,     509.2,     3270.,    514.74,     3300.,    519.28,     3330.,    522.36
   3360.,    527.54,     3390.,    533.31,     3420.,    535.59,     3450.,    538.47
   3480.,    541.33,     3510.,    545.22,     3540.,    548.48,     3570.,    553.38
   3600.,     558.4,     3630.,    560.82,     3660.,    564.28,     3690.,    567.59
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   3840.,    584.61,     3870.,    587.99,     3900.,    590.35,     3930.,    592.64
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   4080.,    608.87,     4110.,    613.01,     4140.,    616.42,     4170.,     617.9
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   4440.,    643.43,     4470.,    647.38,     4500.,    649.58,     4530.,    652.31
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```

5760.,	751.9,	5790.,	753.9,	5820.,	756.5,	5850.,	758.7
5880.,	760.5,	5910.,	763.2,	5940.,	765.,	5970.,	767.2
6000.,	769.1,	6030.,	771.3,	6060.,	773.2,	6090.,	774.7
6120.,	777.1,	6150.,	779.3,	6180.,	781.6,	6210.,	783.7
6240.,	785.4,	6270.,	787.6,	6300.,	789.3,	6330.,	791.
6360.,	792.6,	6390.,	794.7,	6420.,	794.5,	6450.,	794.1
6480.,	796.4,	6510.,	793.1,	6540.,	792.8,	6570.,	794.
6600.,	795.,	6630.,	796.,	6660.,	794.4,	6690.,	793.7
6720.,	794.,	6750.,	794.9,	6780.,	794.5,	6810.,	794.5
6840.,	794.8,	6870.,	795.3,	6900.,	795.9,	6930.,	796.7
6960.,	796.6,	6990.,	797.2,	7020.,	795.7,	7050.,	795.6
7080.,	796.,	7110.,	796.6,	7140.,	797.,	7170.,	797.
7200.,	795.5,	7230.,	795.2,	7260.,	794.9,	7290.,	795.2
7320.,	795.5,	7350.,	796.,	7380.,	796.,	7410.,	795.5
7440.,	796.2,	7470.,	796.4,	7500.,	796.8,	7530.,	796.7
7560.,	796.9,	7590.,	797.,	7620.,	797.8,	7650.,	795.6
7680.,	795.1,	7710.,	795.3,	7740.,	795.3,	7770.,	795.4
7800.,	795.6,	7830.,	794.8,	7860.,	794.9,	7890.,	795.5
7920.,	795.8,	7950.,	795.5,	7980.,	795.,	8010.,	795.4
8040.,	796.,	8070.,	795.8,	8100.,	796.1,	8130.,	796.
8160.,	796.3,	8190.,	796.9,	8220.,	797.,	8250.,	797.2
8280.,	797.5,	8310.,	798.,	8340.,	798.4,	8370.,	798.5
8400.,	798.7,	8430.,	799.,	8460.,	798.,	8490.,	798.2
8520.,	798.3,	8550.,	798.,	8580.,	798.4,	8610.,	798.7
8640.,	799.,	8670.,	799.3,	8700.,	799.3,	8730.,	798.6
8760.,	798.9,	8790.,	798.9,	8820.,	798.8,	8850.,	798.6
8880.,	798.8,	8910.,	799.2,	8940.,	799.4,	8970.,	798.8
9000.,	799.1,	9030.,	799.4,	9060.,	799.7,	9090.,	799.9
9120.,	798.6,	9150.,	797.9,	9180.,	798.1,	9210.,	798.4
9240.,	798.5,	9270.,	797.9,	9300.,	797.9,	9330.,	798.1
9360.,	798.5,	9390.,	798.2,	9420.,	798.2,	9450.,	798.2
9480.,	798.5,	9510.,	799.,	9540.,	798.7,	9570.,	798.6
9600.,	798.9,	9630.,	799.2,	9660.,	799.3,	9690.,	799.4
9720.,	799.4,	9750.,	799.8,	9780.,	800.2,	9810.,	799.7
9840.,	799.2,	9870.,	798.9,	9900.,	799.1,	9930.,	799.3
9960.,	799.1,	9990.,	798.9,	10020.,	799.,	10050.,	799.1
10080.,	799.2,	10110.,	799.4,	10140.,	799.1,	10170.,	799.2
10200.,	799.3,	10230.,	799.5,	10260.,	799.6,	10290.,	799.5
10320.,	799.8,	10350.,	800.,	10380.,	800.2,	10410.,	800.3
10440.,	800.1,	10470.,	800.3,	10500.,	799.5,	10530.,	798.9
10560.,	798.4,	10590.,	797.8,	10620.,	797.4,	10650.,	797.6
10680.,	797.4,	10710.,	797.,	10740.,	797.3,	10770.,	797.5
10800.,	797.4,	10830.,	797.3,	10860.,	797.2,	10890.,	797.5
10920.,	797.8,	10950.,	797.7,	10980.,	797.3,	11010.,	797.4
11040.,	797.1,	11070.,	797.7,	11100.,	798.2,	11130.,	798.4
11160.,	798.4,	11190.,	798.5,	11220.,	798.8,	11250.,	799.2
11280.,	799.5,	11310.,	799.2,	11340.,	799.3,	11370.,	799.9
11400.,	800.3,	11430.,	800.4,	11460.,	800.4,	11490.,	800.6
11520.,	801.2,	11550.,	801.5,	11580.,	801.4,	11610.,	801.4
11640.,	800.2,	11670.,	799.9,	11700.,	799.8,	11730.,	799.6
11760.,	799.5,	11790.,	799.8,	11820.,	799.7,	11850.,	799.8
11880.,	799.6,	11910.,	799.4,	11940.,	799.6,	11970.,	799.8
12000.,	799.8,	12030.,	799.5,	12060.,	799.4,	12090.,	799.8
12120.,	799.9,	12150.,	799.9,	12180.,	799.7,	12210.,	799.6
12240.,	800.1,	12270.,	800.1,	12300.,	800.,	12330.,	800.
12360.,	800.,	12390.,	800.1,	12420.,	800.4,	12450.,	800.1
12480.,	800.1,	12510.,	800.2,	12540.,	800.6,	12570.,	800.7
12600.,	800.7,	12630.,	800.5,	12660.,	800.7,	12690.,	800.9
12720.,	801.3,	12750.,	801.2,	12780.,	801.2,	12810.,	801.3
12840.,	801.7,	12870.,	801.8,	12900.,	801.8,	12930.,	801.7

12960.,	802.1,	12990.,	802.5,	13020.,	802.5,	13050.,	802.6
13080.,	800.7,	13110.,	800.6,	13140.,	800.4,	13170.,	799.8
13200.,	799.4,	13230.,	799.1,	13260.,	798.8,	13290.,	799.6
13320.,	799.1,	13350.,	798.5,	13380.,	799.4,	13410.,	799.3
13440.,	798.8,	13470.,	799.4,	13500.,	799.1,	13530.,	798.7
13560.,	798.6,	13590.,	799.8,	13620.,	799.5,	13650.,	799.3
13680.,	799.4,	13710.,	799.6,	13740.,	799.7,	13770.,	799.6
13800.,	799.5,	13830.,	799.8,	13860.,	800.,	13890.,	799.9
13920.,	799.9,	13950.,	799.9,	13980.,	800.1,	14010.,	800.2
14040.,	800.4,	14070.,	800.2,	14100.,	800.1,	14130.,	800.5
14160.,	800.7,	14190.,	800.7,	14220.,	800.5,	14250.,	800.5
14280.,	800.8,	14310.,	801.1,	14340.,	801.1,	14370.,	801.
14400.,	801.1,	14430.,	801.4,	14460.,	801.6,	14490.,	801.6
14520.,	801.5,	14550.,	801.7,	14580.,	802.,	14610.,	802.2
14640.,	802.2,	14670.,	802.2,	14700.,	802.5,	14730.,	802.8
14760.,	802.9,	14790.,	802.9,	14820.,	802.9,	14850.,	803.1
14880.,	803.4,	14910.,	802.6,	14940.,	801.9,	14970.,	801.7
15000.,	801.8,	15030.,	801.9,	15060.,	801.8,	15090.,	801.5
15120.,	801.4,	15150.,	801.6,	15180.,	801.7,	15210.,	801.5
15240.,	801.2,	15270.,	801.1,	15300.,	797.4,	15330.,	792.9
15360.,	796.3,	15390.,	803.7,	15420.,	801.1,	15450.,	798.9
15480.,	797.2,	15510.,	796.8,	15540.,	797.,	15570.,	797.
15600.,	796.8,	15630.,	796.6,	15660.,	796.4,	15690.,	796.5
15720.,	796.5,	15750.,	796.3,	15780.,	796.5,	15810.,	796.3
15840.,	796.4,	15870.,	796.5,	15900.,	796.9,	15930.,	796.6
15960.,	796.4,	15990.,	796.5,	16020.,	796.4,	16050.,	796.4
16080.,	796.5,	16110.,	796.4,	16140.,	796.5,	16170.,	796.5
16200.,	796.4,	16230.,	796.4,	16260.,	796.5,	16290.,	796.5
16320.,	796.6,	16350.,	796.4,	16380.,	796.5,	16410.,	796.4
16440.,	796.5,	16470.,	796.8,	16500.,	796.5,	16530.,	796.2
16560.,	797.,	16590.,	797.5,	16620.,	797.7,	16650.,	797.8
16680.,	797.9,	16710.,	798.3,	16740.,	798.6,	16770.,	798.4
16800.,	798.,	16830.,	797.8,	16860.,	797.9,	16890.,	797.8
16920.,	797.7,	16950.,	797.2,	16980.,	797.1,	17010.,	797.2
17040.,	797.2,	17070.,	797.,	17100.,	796.7,	17130.,	796.7
17160.,	796.8,	17190.,	797.,	17220.,	796.9,	17250.,	796.7
17280.,	796.8,	17310.,	796.8,	17340.,	797.1,	17370.,	796.8
17400.,	796.6,	17430.,	796.7,	17460.,	797.2,	17490.,	797.
17520.,	796.8,	17550.,	796.7,	17580.,	796.8,	17610.,	797.
17640.,	796.9,	17670.,	796.7,	17700.,	797.1,	17730.,	797.4
17760.,	797.4,	17790.,	797.2,	17820.,	796.9,	17850.,	796.8
17880.,	796.9,	17910.,	796.9,	17940.,	796.8,	17970.,	796.6
18000.,	796.9,	18030.,	797.1,	18060.,	797.,	18090.,	796.9
18120.,	796.7,	18150.,	797.,	18180.,	797.1,	18210.,	797.2
18240.,	797.3,	18270.,	796.8,	18300.,	796.9,	18330.,	797.1
18360.,	797.,	18390.,	796.9,	18420.,	797.,	18450.,	797.2
18480.,	797.2,	18510.,	797.2,	18540.,	797.2,	18570.,	797.
18600.,	797.,	18630.,	797.2,	18660.,	797.2,	18690.,	796.9
18720.,	796.8,	18750.,	797.1,	18780.,	797.2,	18810.,	797.1
18840.,	796.9,	18870.,	796.9,	18900.,	797.1,	18930.,	797.2
18960.,	797.,	18990.,	796.9,	19020.,	796.9,	19050.,	797.1
19080.,	797.2,	19110.,	797.1,	19140.,	796.9,	19170.,	797.
19200.,	797.1,	19230.,	797.2,	19260.,	797.1,	19290.,	796.9
19320.,	796.9,	19350.,	797.2,	19380.,	797.3,	19410.,	797.1
19440.,	797.,	19470.,	797.2,	19500.,	797.4,	19530.,	797.4
19560.,	797.2,	19590.,	797.1,	19620.,	797.4,	19650.,	797.6
19680.,	797.7,	19710.,	797.4,	19740.,	797.4,	19770.,	797.7
19800.,	797.8,	19830.,	797.7,	19860.,	797.6,	19890.,	797.5
19920.,	797.7,	19950.,	797.9,	19980.,	797.8,	20010.,	797.7
20040.,	797.7,	20070.,	798.,	20100.,	798.1,	20130.,	798.2

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    20160.,      797.9,     20190.,       798.,     20220.,      798.2,     20250.,      798.4
    20280.,      798.3,     20310.,      798.1,     20340.,      798.3,     20370.,      798.6
    20400.,      798.6,     20430.,      798.5,     20460.,      798.4,     20490.,      798.6
    20520.,      798.8,     20550.,      798.8,     20580.,      798.7,     20610.,      798.9
    20640.,      799.1,     20670.,       799.,     20700.,      799.1,     20730.,      798.3
    20760.,       798.,     20790.,       798.,     20820.,      797.6,     20850.,      797.5
    20880.,      797.1,     20910.,      797.4,     20940.,      797.5,     20970.,      797.4
    21000.,      797.4,     21030.,      797.5,     21060.,      797.6,     21090.,       798.
    21120.,      798.1,     21150.,      798.2,     21180.,      798.1,     21210.,      798.3
    21240.,      798.6,     21270.,      798.8,     21300.,      798.6,     21330.,      798.7
    21360.,      798.7,     21390.,       799.,     21420.,       799.,     21450.,      798.8
    21480.,      798.3,     21510.,      798.2,     21540.,       798.,     21570.,      797.9
    21600.,      797.5,     21630.,      797.1,     21660.,      797.2,     21690.,      797.4
    21720.,      797.6,     21750.,      797.2
**
** MATERIALS
**
*Material, name="Lightweight concrete"
*Conductivity
 0.32,800.
*Density
1400.,
*Latent Heat
48000.,104.,145.
*Specific Heat
750.,800.
*Material, name=Mortar_properties
*Conductivity
 1.4,800.
*Density
1900.,
*Latent Heat
89000.,100.,113.
*Specific Heat
4000.,800.
**
** INTERACTION PROPERTIES
**
*Film Property, name=Cold_face
4., 800.
*Film Property, name=Hot_face
25., 800.
**
** PHYSICAL CONSTANTS
**
*Physical Constants, absolute zero=-273., stefan boltzmann=5.67e-08
**
** PREDEFINED FIELDS
**
** Name: Predefined Field-1   Type: Temperature
*Initial Conditions, type=TEMPERATURE
_PickedSet2365, 19.
** ----------------------------------------------------------------
**
** STEP: Heat transfer
**
*Step, name="Heat transfer", inc=10000
*Heat Transfer, end=PERIOD, deltmx=10.
1., 21750., 0.001, 21750.,
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```

```
** INTERACTIONS
**
** Interaction: Bottom_cold_mortar
*Sfilm, amplitude=Furnace_temperature
Bottom_mortar, F, 1., Cold_face
** Interaction: External_hot_faces_specimen
*Sfilm, amplitude=Furnace_temperature
Hot_faces, F, 1., Hot_face
** Interaction: Internal_cold_block_faces
*Sfilm, amplitude=Furnace_temperature
Surf-27(Blocks), F, 1., Cold_face
** Interaction: Internal_cold_mortar_faces
*Sfilm, amplitude=Furnace_temperature
Mortar, F, 1., Cold_face
** Interaction: Radiation_Furnace_temperature
*Sradiate, amplitude=Furnace_temperature
Hot_faces, R, 1., 0.7
** Interaction: Radiation_bottom_mortar
*Sradiate
Bottom_mortar, R, 20., 0.7
** Interaction: Radiation_cold_top_mortar
*Sradiate
Top_mortar, R, 20., 0.7
** Interaction: Top_cold_mortar
*Sfilm, amplitude=Furnace_temperature
Top_mortar, F, 1., Cold_face
**
** OUTPUT REQUESTS
**
*Restart, write, frequency=0
**
** FIELD OUTPUT: F-Output-1
**
*Output, field, variable=PRESELECT
*Output, history, frequency=0
*End Step
```

Thermal analysis data of big walls at 200ºC

```
  *Heading
** Job name: 10_Jun_2010_200_1S Model name: Model-1
** Generated by: Abaqus/CAE Version 6.8-2
*Preprint, echo=NO, model=YES, history=NO, contact=NO
**
** PARTS
**
*Part, name=Block_75x75mm
*Node
      1, 0.0375000015, -0.0375000015,           0.
      2, 0.0375000015, -0.0375000015, 0.0500000007
      3, 0.0375000015, -0.0375000015,  0.100000001
      4, 0.00249999994, -0.0375000015,           0.
      5, 0.00249999994, -0.0375000015, 0.0500000007
      6, 0.00249999994, -0.0375000015,  0.100000001
      7, -0.0375000015, -0.0375000015,           0.
      8, -0.0375000015, -0.0375000015, 0.0500000007
      9, -0.0375000015, -0.0375000015,  0.100000001
     10, 0.0375000015, 0.00549999997,           0.
     11, 0.0375000015, 0.00549999997, 0.0500000007
     12, 0.0375000015, 0.00549999997,  0.100000001
     13, 0.00249999994, 0.00549999997,           0.
     14, 0.00249999994, 0.00549999997, 0.0500000007
     15, 0.00249999994, 0.00549999997,  0.100000001
     16, -0.0375000015, 0.00549999997,           0.
     17, -0.0375000015, 0.00549999997, 0.0500000007
     18, -0.0375000015, 0.00549999997,  0.100000001
     19, 0.0375000015, 0.0375000015,           0.
     20, 0.0375000015, 0.0375000015, 0.0500000007
     21, 0.0375000015, 0.0375000015,  0.100000001
     22, 0.00249999994, 0.0375000015,           0.
     23, 0.00249999994, 0.0375000015, 0.0500000007
     24, 0.00249999994, 0.0375000015,  0.100000001
     25, -0.0375000015, 0.0375000015,           0.
     26, -0.0375000015, 0.0375000015, 0.0500000007
     27, -0.0375000015, 0.0375000015,  0.100000001
*Element, type=DC3D8
1, 10, 11, 14, 13,  1,  2,  5,  4
2, 11, 12, 15, 14,  2,  3,  6,  5
3, 13, 14, 17, 16,  4,  5,  8,  7
4, 14, 15, 18, 17,  5,  6,  9,  8
5, 19, 20, 23, 22, 10, 11, 14, 13
6, 20, 21, 24, 23, 11, 12, 15, 14
7, 22, 23, 26, 25, 13, 14, 17, 16
8, 23, 24, 27, 26, 14, 15, 18, 17
*Nset, nset=_PickedSet2, internal, generate
  1,  27,   1
*Elset, elset=_PickedSet2, internal, generate
 1,  8,  1
*Elset, elset=_Surf-1_S5, internal
 3, 4, 7, 8
*Surface, type=ELEMENT, name=Surf-1
_Surf-1_S5, S5
** Section: LWC blocks
*Solid Section, elset=_PickedSet2, material="Lighweight Concrete Blocks"
1.,
*End Part
**
```

```
*Amplitude, name=External, time=TOTAL TIME
   0.,  20.595,    30.,    21.3,    60.,   24.96,    90.,  33.125
 120.,   45.42,   150.,   59.72,   180.,   73.24,   210.,  84.205
 240.,  89.425,   270.,   91.17,   300.,   90.93,   330.,  90.995
 360.,  93.365,   390.,   98.89,   420., 105.835,   450., 113.445
 480., 119.685,   510., 122.385,   540.,  122.27,   570., 123.795
 600.,  128.73,   630.,  135.48,   660., 142.995,   690., 147.685
 720., 151.135,   750., 152.265,   780., 154.245,   810.,  159.26
 840.,  165.61,   870.,  172.94,   900., 179.225,   930.,   180.6
 960.,  178.38,   990., 179.885,  1020., 186.135,  1050.,   193.8
1080.,  201.49,  1110., 207.095,  1140., 205.745,  1170.,   203.1
1200., 199.255,  1230.,  195.83,  1260.,  191.83,  1290., 188.555
1320., 185.035,  1350., 182.295,  1380., 179.965,  1410., 178.205
1440.,  178.62,  1470.,   181.3,  1500., 184.515,  1530., 189.365
1560.,    194.,  1590., 196.675,  1620., 198.815,  1650.,  199.58
1680.,   198.6,  1710., 196.935,  1740.,  193.75,  1770., 191.325
1800.,  190.83,  1830., 193.475,  1860.,  197.55,  1890.,  198.19
1920., 196.775,  1950., 194.795,  1980., 192.475,  2010.,  191.08
2040.,  193.88,  2070., 198.035,  2100., 198.855,  2130.,  197.93
2160., 196.035,  2190., 194.145,  2220., 192.345,  2250.,   191.7
2280.,  194.91,  2310., 198.145,  2340.,   198.7,  2370., 197.545
2400., 196.025,  2430., 194.155,  2460., 192.595,  2490.,  193.73
2520., 197.195,  2550.,  198.07,  2580., 197.495,  2610., 196.205
2640., 194.395,  2670.,  193.48,  2700.,  194.39,  2730.,  197.55
2760., 199.135,  2790., 198.325,  2820., 197.435,  2850.,  199.26
2880.,  203.77,  2910.,  206.96,  2940., 206.135,  2970.,  204.95
3000., 203.155,  3030., 200.955,  3060.,  199.31,  3090.,  197.36
3120., 196.105,  3150.,  195.51,  3180.,  196.26,  3210., 197.435
3240., 200.085,  3270., 201.305,  3300., 202.265,  3330.,  202.25
3360.,   200.9,  3390., 199.695,  3420.,  199.07,  3450.,  199.31
3480., 200.905,  3510., 202.445,  3540.,  202.54,  3570., 201.705
3600., 200.485,  3630., 199.405,  3660., 199.835,  3690., 200.575
3720., 201.955,  3750., 202.665,  3780., 202.005,  3810., 200.595
3840.,  199.49,  3870.,  199.38,  3900.,  200.96,  3930.,  202.49
3960.,  203.13,  3990., 202.765,  4020., 201.555,  4050., 200.365
4080., 200.325,  4110.,   201.2,  4140.,  202.92,  4170., 203.825
4200., 203.365,  4230., 203.125,  4260., 202.085,  4290., 200.585
4320., 200.045,  4350.,  201.64,  4380., 203.345,  4410., 203.855
4440.,  202.87,  4470.,  202.35,  4500., 200.955,  4530., 200.855
4560.,   201.6,  4590., 203.395,  4620.,  204.13,  4650., 203.645
4680., 202.975,  4710., 201.965,  4740.,  200.59,  4770.,  201.34
4800., 203.485,  4830., 204.545,  4860., 203.545,  4890., 203.125
4920.,  201.38,  4950., 201.245,  4980., 202.485,  5010.,  204.66
5040.,  204.96,  5070., 204.675,  5100.,  203.47,  5130.,   202.2
5160.,  200.98,  5190.,  201.12,  5220., 202.975,  5250., 205.265
5280.,  205.39,  5310.,  204.79,  5340.,  203.85,  5370., 202.505
5400., 201.065,  5430., 201.385,  5460.,  203.21,  5490.,  205.31
5520., 205.445,  5550., 205.385,  5580., 204.055,  5610.,   202.8
5640.,  201.55,  5670.,  200.33,  5700., 198.685,  5730.,  197.57
5760.,  198.97,  5790.,   203.2,  5820.,  205.11,  5850., 205.205
5880.,  204.16,  5910., 203.605,  5940.,  202.16,  5970., 200.935
6000.,  199.43,  6030., 198.685,  6060., 200.305,  6090., 203.935
6120., 205.975,  6150.,  206.74,  6180., 205.755,  6210.,  204.71
6240.,   203.3,  6270.,  202.12,  6300.,   200.7,  6330., 199.815
6360.,  199.25,  6390.,  201.66,  6420.,  204.52,  6450., 205.275
6480., 205.385,  6510.,  204.31,  6540.,  203.25,  6570., 201.985
6600.,  200.85,  6630., 199.965,  6660., 200.545,  6690., 203.655
6720.,  204.99,  6750., 204.915,  6780., 204.165,  6810.,  203.38
6840.,  202.13,  6870.,  200.82,  6900.,  199.69,  6930., 200.265
6960., 203.755,  6990.,  205.03,  7020., 205.825,  7050., 205.045
```

7080.,	203.855,	7110.,	202.52,	7140.,	201.655,	7170.,	200.7
7200.,	199.715,	7230.,	201.55,	7260.,	204.605,	7290.,	206.175
7320.,	205.82,	7350.,	204.855,	7380.,	204.13,	7410.,	202.75
7440.,	201.705,	7470.,	200.465,	7500.,	200.55,	7530.,	203.21
7560.,	205.71,	7590.,	206.335,	7620.,	205.685,	7650.,	204.88
7680.,	203.91,	7710.,	202.945,	7740.,	201.78,	7770.,	200.84
7800.,	200.355,	7830.,	201.7,	7860.,	204.97,	7890.,	206.105
7920.,	206.01,	7950.,	205.465,	7980.,	204.28,	8010.,	203.345
8040.,	202.55,	8070.,	200.865,	8100.,	200.31,	8130.,	200.82
8160.,	203.305,	8190.,	205.64,	8220.,	206.07,	8250.,	205.05
8280.,	204.625,	8310.,	203.745,	8340.,	202.615,	8370.,	201.685
8400.,	200.725,	8430.,	201.24,	8460.,	204.055,	8490.,	204.85
8520.,	204.665,	8550.,	203.985,	8580.,	203.285,	8610.,	202.38
8640.,	201.4,	8670.,	201.745,	8700.,	204.305,	8730.,	206.32
8760.,	206.7,	8790.,	206.095,	8820.,	205.025,	8850.,	204.205
8880.,	203.465,	8910.,	202.245,	8940.,	200.985,	8970.,	200.25
9000.,	200.535,	9030.,	204.66,	9060.,	208.04,	9090.,	209.04
9120.,	208.31,	9150.,	207.675,	9180.,	206.655,	9210.,	205.615
9240.,	204.62,	9270.,	203.34,	9300.,	202.79,	9330.,	201.585
9360.,	200.61,	9390.,	200.09,	9420.,	199.515,	9450.,	199.32
9480.,	199.685,	9510.,	200.39,	9540.,	201.8,	9570.,	203.17
9600.,	204.01,	9630.,	204.39,	9660.,	204.825,	9690.,	204.89
9720.,	204.64,	9750.,	203.9,	9780.,	202.62,	9810.,	202.28
9840.,	202.295,	9870.,	202.88,	9900.,	203.165,	9930.,	203.605
9960.,	204.475,	9990.,	204.935,	10020.,	204.86,	10050.,	204.125
10080.,	203.375,	10110.,	202.55,	10140.,	202.56,	10170.,	203.055
10200.,	203.49,	10230.,	203.755,	10260.,	204.665,	10290.,	204.975
10320.,	205.18,	10350.,	204.555,	10380.,	203.685,	10410.,	202.845
10440.,	202.265,	10470.,	201.51,	10500.,	200.625,	10530.,	199.32
10560.,	198.74,	10590.,	198.995,	10620.,	201.05,	10650.,	203.87
10680.,	206.345,	10710.,	206.72,	10740.,	206.57,	10770.,	205.8
10800.,	204.75,	10830.,	203.75,	10860.,	202.855,	10890.,	201.965
10920.,	201.09,	10950.,	200.145,	10980.,	199.56,	11010.,	199.31
11040.,	199.37,	11070.,	199.785,	11100.,	200.22,	11130.,	200.69
11160.,	201.2,	11190.,	201.91,	11220.,	202.505,	11250.,	203.13
11280.,	203.765,	11310.,	204.025,	11340.,	203.94,	11370.,	203.5
11400.,	202.845,	11430.,	202.005,	11460.,	201.48,	11490.,	201.685
11520.,	202.1,	11550.,	202.675,	11580.,	203.59,	11610.,	203.86
11640.,	203.805,	11670.,	203.105,	11700.,	202.265,	11730.,	202.11
11760.,	202.58,	11790.,	202.97,	11820.,	203.89,	11850.,	203.99
11880.,	203.75,	11910.,	203.05,	11940.,	202.45,	11970.,	201.875
12000.,	201.77,	12030.,	202.085,	12060.,	202.73,	12090.,	203.325
12120.,	204.415,	12150.,	204.31,	12180.,	204.065,	12210.,	203.63
12240.,	202.77,	12270.,	202.,	12300.,	201.82,	12330.,	202.295
12360.,	202.985,	12390.,	203.245,	12420.,	202.965,	12450.,	202.62
12480.,	201.6,	12510.,	201.1,	12540.,	200.61,	12570.,	199.875
12600.,	199.28,	12630.,	198.91,	12660.,	199.315,	12690.,	202.065
12720.,	204.55,	12750.,	205.53,	12780.,	205.66,	12810.,	205.415
12840.,	204.395,	12870.,	203.87,	12900.,	203.05,	12930.,	202.03
12960.,	201.125,	12990.,	200.365,	13020.,	199.7,	13050.,	199.44
13080.,	201.94,	13110.,	204.07,	13140.,	204.985,	13170.,	205.05
13200.,	204.495,	13230.,	203.9,	13260.,	202.89,	13290.,	202.355
13320.,	201.435,	13350.,	200.67,	13380.,	200.015,	13410.,	200.18
13440.,	202.09,	13470.,	203.81,	13500.,	204.445,	13530.,	204.325
13560.,	203.995,	13590.,	203.37,	13620.,	202.685,	13650.,	201.86
13680.,	201.135,	13710.,	200.485,	13740.,	200.91,	13770.,	203.125
13800.,	204.78,	13830.,	205.085,	13860.,	205.005,	13890.,	204.38
13920.,	203.805,	13950.,	203.125,	13980.,	202.195,	14010.,	201.625
14040.,	201.035,	14070.,	200.985,	14100.,	202.765,	14130.,	204.085
14160.,	204.73,	14190.,	204.495,	14220.,	203.98,	14250.,	203.59

14280.,	202.74,	14310.,	201.955,	14340.,	201.275,	14370.,	200.505
14400.,	201.485,	14430.,	203.76,	14460.,	204.765,	14490.,	205.245
14520.,	205.14,	14550.,	204.88,	14580.,	204.065,	14610.,	203.335
14640.,	202.65,	14670.,	202.005,	14700.,	201.3,	14730.,	200.69
14760.,	202.185,	14790.,	204.855,	14820.,	205.865,	14850.,	206.185
14880.,	205.865,	14910.,	205.34,	14940.,	204.695,	14970.,	203.95
15000.,	203.055,	15030.,	202.31,	15060.,	201.615,	15090.,	200.89
15120.,	200.78,	15150.,	202.19,	15180.,	204.72,	15210.,	205.78
15240.,	206.045,	15270.,	205.465,	15300.,	204.855,	15330.,	204.065
15360.,	203.52,	15390.,	202.92,	15420.,	201.92,	15450.,	201.55
15480.,	201.25,	15510.,	202.25,	15540.,	203.15,	15570.,	203.57
15600.,	203.575,	15630.,	203.31,	15660.,	202.675,	15690.,	202.105
15720.,	201.465,	15750.,	201.025,	15780.,	200.4,	15810.,	199.82
15840.,	199.205,	15870.,	198.85,	15900.,	200.305,	15930.,	204.06
15960.,	206.46,	15990.,	207.155,	16020.,	207.12,	16050.,	206.585
16080.,	206.09,	16110.,	205.37,	16140.,	204.555,	16170.,	203.6
16200.,	203.075,	16230.,	202.235,	16260.,	201.755,	16290.,	201.05
16320.,	200.465,	16350.,	199.79,	16380.,	199.2,	16410.,	199.01
16440.,	199.31,	16470.,	200.045,	16500.,	200.785,	16530.,	201.875
16560.,	202.74,	16590.,	203.28,	16620.,	203.105,	16650.,	203.015
16680.,	202.49,	16710.,	202.065,	16740.,	201.4,	16770.,	200.895
16800.,	200.245,	16830.,	200.005,	16860.,	200.465,	16890.,	201.61
16920.,	202.815,	16950.,	203.195,	16980.,	203.,	17010.,	202.375
17040.,	202.115,	17070.,	201.595,	17100.,	201.01,	17130.,	200.41
17160.,	200.325,	17190.,	201.155,	17220.,	202.335,	17250.,	202.955
17280.,	203.225,	17310.,	203.,	17340.,	202.54,	17370.,	201.87
17400.,	201.465,	17430.,	200.855,	17460.,	200.15,	17490.,	200.35
17520.,	201.545,	17550.,	202.97,	17580.,	203.715,	17610.,	203.73
17640.,	203.28,	17670.,	202.83,	17700.,	202.385,	17730.,	201.77
17760.,	200.96,	17790.,	200.525,	17820.,	200.43,	17850.,	201.305
17880.,	202.795,	17910.,	203.53,	17940.,	203.66,	17970.,	203.28
18000.,	203.1,	18030.,	202.52,	18060.,	201.825,	18090.,	201.21
18120.,	200.58,	18150.,	200.48,	18180.,	201.275,	18210.,	202.83
18240.,	204.205,	18270.,	204.505,	18300.,	204.29,	18330.,	203.795
18360.,	203.245,	18390.,	202.585,	18420.,	202.175,	18450.,	201.47
18480.,	201.145,	18510.,	200.75,	18540.,	201.14,	18570.,	202.535
18600.,	203.335,	18630.,	203.765,	18660.,	203.32,	18690.,	203.095
18720.,	202.705,	18750.,	202.185,	18780.,	201.525,	18810.,	200.975
18840.,	200.57,	18870.,	200.825,	18900.,	202.425,	18930.,	204.02
18960.,	204.24,	18990.,	204.26,	19020.,	203.925,	19050.,	203.445
19080.,	202.945,	19110.,	202.26,	19140.,	201.655,	19170.,	201.105
19200.,	200.685,	19230.,	201.305,	19260.,	202.8,	19290.,	203.32
19320.,	203.465,	19350.,	203.225,	19380.,	202.95,	19410.,	202.585
19440.,	202.035,	19470.,	201.575,	19500.,	201.18,	19530.,	201.53
19560.,	203.19,	19590.,	204.185,	19620.,	204.285,	19650.,	204.125
19680.,	203.81,	19710.,	203.11,	19740.,	202.63,	19770.,	202.17
19800.,	201.51,	19830.,	201.065,	19860.,	201.32,	19890.,	202.815
19920.,	204.02,	19950.,	204.65,	19980.,	204.62,	20010.,	204.395
20040.,	203.82,	20070.,	203.385,	20100.,	202.63,	20130.,	202.15
20160.,	201.815,	20190.,	201.385,	20220.,	201.655,	20250.,	203.06
20280.,	204.445,	20310.,	205.06,	20340.,	204.885,	20370.,	204.51
20400.,	204.16,	20430.,	203.545,	20460.,	202.955,	20490.,	202.26
20520.,	201.755,	20550.,	201.185,	20580.,	201.125,	20610.,	202.495
20640.,	204.085,	20670.,	204.94,	20700.,	205.15,	20730.,	204.725
20760.,	204.425,	20790.,	203.815,	20820.,	203.075,	20850.,	202.625
20880.,	202.125,	20910.,	201.49,	20940.,	201.03,	20970.,	201.895
21000.,	203.785,	21030.,	204.95,	21060.,	204.96,	21090.,	204.93
21120.,	204.46,	21150.,	203.945,	21180.,	203.32,	21210.,	202.77
21240.,	202.265,	21270.,	201.78,	21300.,	201.415,	21330.,	202.35
21360.,	204.12,	21390.,	204.865,	21420.,	204.76,	21450.,	204.45

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    21480.,    204.225,     21510.,     203.615,     21540.,      203.03,     21570.,      202.67
    21600.,    202.015,     21630.,     201.475,     21660.,      201.38,     21690.,       203.3
    21720.,     204.61,     21750.,      205.11,     21780.,      205.38,     21810.,      205.08
    21840.,     204.61,     21870.,     204.175,     21900.,     203.445,     21930.,     203.005
    21960.,     202.53,     21990.,      202.06,     22020.,      201.53,     22050.,      201.39
    22080.,    202.535,     22110.,     204.235,     22140.,     204.965
**
** MATERIALS
**
*Material, name="Lightweight Concrete Blocks"
*Conductivity
 0.33,200.
*Density
1400.,
*Latent Heat
48000.,100.,119.
*Specific Heat
660.,200.
*Material, name=Mortar
*Conductivity
 2.9,200.
*Density
1900.,
*Latent Heat
89000.,100.,115.
*Specific Heat
7700.,200.
**
** INTERACTION PROPERTIES
**
*Film Property, name=Cold
4., 200.
*Film Property, name=Hot
25., 200.
**
** PHYSICAL CONSTANTS
**
*Physical Constants, absolute zero=-273., stefan boltzmann=5.6697e-08
**
** PREDEFINED FIELDS
**
** Name: Initial temperature   Type: Temperature
*Initial Conditions, type=TEMPERATURE
_PickedSet10103, 20.
** ----------------------------------------------------------------
**
** STEP: Heat_transfer
**
*Step, name=Heat_transfer, inc=100000
*Heat Transfer, end=PERIOD, deltmx=10.
0.1, 22140., 0.0001, 22140.,
**
** INTERACTIONS
**
** Interaction: Cold_faces
*Sfilm
External_cold_faces, F, 1., Cold
** Interaction: Hot_face
*Sfilm, amplitude=External
Hot_face, F, 1., Hot
```

```
** Interaction: Internal_cold_block_faces
*Sfilm, amplitude=External
Cold_blocks, F, 1., Cold
** Interaction: Internal_cold_mortar_faces
*Sfilm, amplitude=External
Cold_mortar, F, 1., Cold
** Interaction: Radiation_cold_faces
*Sradiate
External_cold_faces, R, 20., 0.7
** Interaction: Radiation_furnace
*Sradiate, amplitude=External
Hot_face, R, 1., 0.7
**
** OUTPUT REQUESTS
**
*Restart, write, frequency=0
**
** FIELD OUTPUT: F-Output-1
**
*Output, field, variable=PRESELECT
*Output, history, frequency=0
```

Thermal analysis data of big walls at 400ºC

*Amplitude, name=External, time=TOTAL TIME

0.,	19.105,	30.,	20.02,	60.,	24.775,	90.,	35.005
120.,	49.465,	150.,	65.685,	180.,	81.155,	210.,	93.655
240.,	99.46,	270.,	101.155,	300.,	100.72,	330.,	98.895
360.,	97.94,	390.,	100.515,	420.,	106.47,	450.,	114.815
480.,	123.725,	510.,	131.575,	540.,	135.425,	570.,	136.585
600.,	135.455,	630.,	137.26,	660.,	142.595,	690.,	150.115
720.,	158.56,	750.,	164.16,	780.,	166.365,	810.,	169.54
840.,	173.24,	870.,	177.66,	900.,	183.305,	930.,	189.19
960.,	195.135,	990.,	196.815,	1020.,	197.895,	1050.,	201.31
1080.,	207.035,	1110.,	214.105,	1140.,	221.135,	1170.,	226.625
1200.,	226.92,	1230.,	226.065,	1260.,	230.205,	1290.,	237.015
1320.,	245.53,	1350.,	255.56,	1380.,	265.92,	1410.,	271.265
1440.,	272.295,	1470.,	271.025,	1500.,	271.305,	1530.,	272.375
1560.,	277.88,	1590.,	284.845,	1620.,	292.185,	1650.,	299.415
1680.,	303.845,	1710.,	305.665,	1740.,	308.205,	1770.,	310.57
1800.,	312.725,	1830.,	319.74,	1860.,	327.44,	1890.,	333.785
1920.,	339.58,	1950.,	340.84,	1980.,	346.67,	2010.,	352.125
2040.,	357.02,	2070.,	362.435,	2100.,	365.41,	2130.,	369.775
2160.,	374.07,	2190.,	379.915,	2220.,	384.935,	2250.,	389.915
2280.,	395.525,	2310.,	399.28,	2340.,	398.29,	2370.,	390.65
2400.,	385.445,	2430.,	384.255,	2460.,	385.59,	2490.,	388.84
2520.,	391.955,	2550.,	393.135,	2580.,	393.315,	2610.,	392.905
2640.,	391.945,	2670.,	390.53,	2700.,	388.71,	2730.,	387.26
2760.,	388.955,	2790.,	390.72,	2820.,	392.31,	2850.,	391.695
2880.,	390.98,	2910.,	391.075,	2940.,	392.755,	2970.,	393.
3000.,	392.875,	3030.,	392.52,	3060.,	393.31,	3090.,	393.165
3120.,	394.345,	3150.,	395.21,	3180.,	395.325,	3210.,	395.33
3240.,	395.12,	3270.,	395.535,	3300.,	395.87,	3330.,	395.99
3360.,	396.605,	3390.,	396.325,	3420.,	396.13,	3450.,	394.61
3480.,	394.4,	3510.,	393.585,	3540.,	393.465,	3570.,	395.1
3600.,	396.32,	3630.,	396.725,	3660.,	396.335,	3690.,	396.365
3720.,	396.07,	3750.,	396.09,	3780.,	395.7,	3810.,	395.985
3840.,	396.135,	3870.,	395.85,	3900.,	395.65,	3930.,	395.95
3960.,	396.735,	3990.,	397.005,	4020.,	397.08,	4050.,	396.905
4080.,	397.72,	4110.,	397.455,	4140.,	397.9,	4170.,	398.455
4200.,	397.88,	4230.,	398.185,	4260.,	398.225,	4290.,	398.935
4320.,	398.93,	4350.,	397.875,	4380.,	397.235,	4410.,	395.95
4440.,	395.04,	4470.,	395.14,	4500.,	396.2,	4530.,	397.38
4560.,	398.09,	4590.,	398.395,	4620.,	398.37,	4650.,	398.19
4680.,	397.525,	4710.,	396.455,	4740.,	397.57,	4770.,	397.555
4800.,	397.665,	4830.,	397.,	4860.,	398.445,	4890.,	398.535
4920.,	398.84,	4950.,	398.215,	4980.,	398.88,	5010.,	398.925
5040.,	398.48,	5070.,	398.925,	5100.,	398.42,	5130.,	398.89
5160.,	398.815,	5190.,	399.375,	5220.,	399.405,	5250.,	400.015
5280.,	400.03,	5310.,	400.865,	5340.,	400.87,	5370.,	400.345
5400.,	400.17,	5430.,	399.56,	5460.,	398.71,	5490.,	398.075
5520.,	397.495,	5550.,	398.455,	5580.,	400.01,	5610.,	400.24
5640.,	400.06,	5670.,	399.585,	5700.,	399.56,	5730.,	399.75
5760.,	399.175,	5790.,	398.83,	5820.,	399.12,	5850.,	399.905
5880.,	400.465,	5910.,	400.3,	5940.,	399.45,	5970.,	400.135
6000.,	399.715,	6030.,	399.79,	6060.,	400.035,	6090.,	400.255
6120.,	401.025,	6150.,	401.98,	6180.,	401.74,	6210.,	401.85
6240.,	401.925,	6270.,	402.14,	6300.,	401.47,	6330.,	400.915
6360.,	399.865,	6390.,	398.615,	6420.,	398.665,	6450.,	399.165
6480.,	399.425,	6510.,	401.26,	6540.,	401.535,	6570.,	401.12
6600.,	400.87,	6630.,	399.475,	6660.,	400.12,	6690.,	400.65
6720.,	400.615,	6750.,	400.74,	6780.,	400.735,	6810.,	400.07

6840.,	400.735,	6870.,	400.665,	6900.,	400.825,	6930.,	400.97
6960.,	400.64,	6990.,	400.61,	7020.,	401.355,	7050.,	401.64
7080.,	401.895,	7110.,	401.59,	7140.,	401.205,	7170.,	401.305
7200.,	401.155,	7230.,	401.035,	7260.,	401.03,	7290.,	400.93
7320.,	401.03,	7350.,	401.625,	7380.,	401.675,	7410.,	402.08
7440.,	402.06,	7470.,	402.76,	7500.,	403.11,	7530.,	403.37
7560.,	403.92,	7590.,	404.125,	7620.,	403.29,	7650.,	401.665
7680.,	399.86,	7710.,	398.7,	7740.,	398.68,	7770.,	399.27
7800.,	400.335,	7830.,	400.41,	7860.,	401.76,	7890.,	402.925
7920.,	403.21,	7950.,	402.88,	7980.,	402.415,	8010.,	401.255
8040.,	400.685,	8070.,	401.11,	8100.,	400.005,	8130.,	398.275
8160.,	396.6,	8190.,	396.135,	8220.,	398.155,	8250.,	404.98
8280.,	412.83,	8310.,	414.405,	8340.,	412.24,	8370.,	409.615
8400.,	407.035,	8430.,	404.26,	8460.,	401.815,	8490.,	399.38
8520.,	396.915,	8550.,	394.77,	8580.,	395.295,	8610.,	397.755
8640.,	400.585,	8670.,	402.835,	8700.,	403.57,	8730.,	403.365
8760.,	402.31,	8790.,	401.29,	8820.,	400.105,	8850.,	399.825
8880.,	399.595,	8910.,	400.98,	8940.,	401.425,	8970.,	400.95
9000.,	400.975,	9030.,	400.545,	9060.,	400.125,	9090.,	399.88
9120.,	401.3,	9150.,	401.81,	9180.,	402.01,	9210.,	401.775
9240.,	401.67,	9270.,	401.18,	9300.,	400.58,	9330.,	400.61
9360.,	400.37,	9390.,	400.68,	9420.,	401.37,	9450.,	401.265
9480.,	401.59,	9510.,	401.91,	9540.,	401.83,	9570.,	401.67
9600.,	402.08,	9630.,	401.98,	9660.,	401.6,	9690.,	401.85
9720.,	402.085,	9750.,	402.495,	9780.,	402.735,	9810.,	403.01
9840.,	402.675,	9870.,	403.,	9900.,	403.095,	9930.,	403.115
9960.,	403.195,	9990.,	403.485,	10020.,	403.62,	10050.,	403.91
10080.,	404.135,	10110.,	404.455,	10140.,	404.325,	10170.,	404.47
10200.,	404.455,	10230.,	404.275,	10260.,	404.35,	10290.,	404.365
10320.,	405.03,	10350.,	404.79,	10380.,	403.935,	10410.,	402.22
10440.,	400.19,	10470.,	398.595,	10500.,	398.4,	10530.,	399.545
10560.,	400.52,	10590.,	401.605,	10620.,	402.75,	10650.,	403.27
10680.,	402.52,	10710.,	401.47,	10740.,	400.715,	10770.,	400.235
10800.,	400.63,	10830.,	402.445,	10860.,	402.99,	10890.,	402.915
10920.,	402.185,	10950.,	401.645,	10980.,	400.76,	11010.,	399.53
11040.,	397.49,	11070.,	396.645,	11100.,	398.55,	11130.,	404.235
11160.,	412.21,	11190.,	414.925,	11220.,	413.78,	11250.,	411.36
11280.,	408.69,	11310.,	406.845,	11340.,	404.835,	11370.,	402.62
11400.,	400.705,	11430.,	398.945,	11460.,	396.96,	11490.,	395.615
11520.,	395.8,	11550.,	398.26,	11580.,	401.05,	11610.,	402.88
11640.,	402.925,	11670.,	402.375,	11700.,	401.795,	11730.,	401.095
11760.,	400.56,	11790.,	399.63,	11820.,	399.2,	11850.,	399.67
11880.,	400.465,	11910.,	400.615,	11940.,	400.42,	11970.,	399.985
12000.,	400.65,	12030.,	401.16,	12060.,	400.99,	12090.,	400.23
12120.,	400.105,	12150.,	400.135,	12180.,	399.7,	12210.,	399.845
12240.,	400.805,	12270.,	401.535,	12300.,	401.63,	12330.,	401.805
12360.,	401.95,	12390.,	402.23,	12420.,	402.45,	12450.,	402.505
12480.,	402.6,	12510.,	402.18,	12540.,	401.85,	12570.,	401.1
12600.,	400.375,	12630.,	399.765,	12660.,	399.055,	12690.,	399.72
12720.,	400.52,	12750.,	400.87,	12780.,	401.205,	12810.,	401.03
12840.,	400.675,	12870.,	400.24,	12900.,	400.19,	12930.,	399.975
12960.,	399.805,	12990.,	399.92,	13020.,	400.175,	13050.,	400.26
13080.,	400.045,	13110.,	399.74,	13140.,	399.82,	13170.,	400.165
13200.,	400.78,	13230.,	401.08,	13260.,	401.63,	13290.,	401.735
13320.,	401.7,	13350.,	401.82,	13380.,	402.065,	13410.,	401.94
13440.,	402.1,	13470.,	402.175,	13500.,	402.21,	13530.,	402.465
13560.,	402.445,	13590.,	402.265,	13620.,	402.2,	13650.,	401.78
13680.,	401.225,	13710.,	400.58,	13740.,	399.78,	13770.,	399.685
13800.,	400.515,	13830.,	401.385,	13860.,	401.615,	13890.,	401.745
13920.,	401.395,	13950.,	401.16,	13980.,	400.82,	14010.,	400.6

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14040.,   400.51,  14070.,   400.18,  14100.,   400.28,  14130.,  400.545
14160.,   401.46,  14190.,   401.68,  14220.,  401.395,  14250.,    401.3
14280.,   401.16,  14310.,  400.895,  14340.,   400.38,  14370.,   400.52
14400.,    400.1,  14430.,  401.135,  14460.,   401.33,  14490.,  401.215
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14760.,   401.86,  14790.,   402.16,  14820.,  402.155,  14850.,   402.19
14880.,   402.71,  14910.,   402.68,  14940.,   403.02,  14970.,  402.735
15000.,  401.715,  15030.,   400.89,  15060.,   399.07,  15090.,   397.85
15120.,  398.195,  15150.,  398.795,  15180.,   399.85,  15210.,   400.79
15240.,  401.595,  15270.,  402.785,  15300.,   402.44,  15330.,   401.64
15360.,   401.33,  15390.,  400.755,  15420.,  400.235,  15450.,   399.89
15480.,    400.3,  15510.,  401.675,  15540.,  402.365,  15570.,    402.3
15600.,   402.12,  15630.,   401.88,  15660.,   401.64,  15690.,   401.55
15720.,   401.36,  15750.,  400.995,  15780.,  400.915,  15810.,   400.84
15840.,  400.565,  15870.,   400.61,  15900.,  400.865,  15930.,  400.735
15960.,   400.93,  15990.,   401.72
**
** MATERIALS
**
*Material, name="Lighweight Concrete Blocks"
*Conductivity
 0.33,400.
*Density
1400.,
*Latent Heat
48000.,100.,119.
*Specific Heat
700.,400.
*Material, name=Mortar
*Conductivity
 1.4,400.
*Density
1900.,
*Latent Heat
89000.,100.,115.
*Specific Heat
5000.,400.
**
** INTERACTION PROPERTIES
**
*Film Property, name=Cold
4., 400.
*Film Property, name=Hot
25., 400.
**
** PHYSICAL CONSTANTS
**
*Physical Constants, absolute zero=-273., stefan boltzmann=5.6697e-08
**
** PREDEFINED FIELDS
**
** Name: Initial temperature   Type: Temperature
*Initial Conditions, type=TEMPERATURE
_PickedSet10103, 20.
** ----------------------------------------------------------------
**
** STEP: Heat_transfer
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*Step, name=Heat_transfer, inc=100000
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*Heat Transfer, end=PERIOD, deltmx=10.
0.1, 15990., 0.0001, 15990.,
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** INTERACTIONS
**
** Interaction: Cold_faces
*Sfilm
External_cold_faces, F, 1., Cold
** Interaction: Hot_face
*Sfilm, amplitude=External
Hot_face, F, 1., Hot
** Interaction: Internal_cold_block_faces
*Sfilm, amplitude=External
Cold_blocks, F, 1., Cold
** Interaction: Internal_cold_mortar_faces
*Sfilm, amplitude=External
Cold_mortar, F, 1., Cold
** Interaction: Radiation_cold_faces
*Sradiate
External_cold_faces, R, 20., 0.7
** Interaction: Radiation_furnace
*Sradiate, amplitude=External
Hot_face, R, 1., 0.7
**
** OUTPUT REQUESTS
**
*Restart, write, frequency=0
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** FIELD OUTPUT: F-Output-1
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*Output, field, variable=PRESELECT
*Output, history, frequency=0
*End Step
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Thermal analysis data of big walls at 600ºC

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*Amplitude, name=External, time=TOTAL TIME
0., 20.94, 30., 20.95, 60., 21.06, 90., 21.99
120., 24.745, 150., 32.815, 180., 46.585, 210., 63.185
240., 80.305, 270., 93.98, 300., 103.685, 330., 109.67
360., 111.935, 390., 111.15, 420., 110.225, 450., 111.045
480., 113.09, 510., 116.42, 540., 121.61, 570., 127.16
600., 133.53, 630., 139.86, 660., 146.005, 690., 151.
720., 155.21, 750., 158.515, 780., 161.68, 810., 164.96
840., 168.29, 870., 172.61, 900., 176.975, 930., 181.86
960., 187.215, 990., 192.775, 1020., 198.105, 1050., 202.92
1080., 206.05, 1110., 210.205, 1140., 215.11, 1170., 221.37
1200., 226.7, 1230., 231.235, 1260., 236.405, 1290., 240.245
1320., 243.335, 1350., 247.355, 1380., 258.09, 1410., 269.825
1440., 275.62, 1470., 276.37, 1500., 275.055, 1530., 276.115
1560., 280.045, 1590., 286.13, 1620., 293.685, 1650., 301.9
1680., 307.655, 1710., 310.645, 1740., 312.595, 1770., 316.115
1800., 321.36, 1830., 326.76, 1860., 331.285, 1890., 336.75
1920., 341.025, 1950., 346.315, 1980., 351.745, 2010., 356.915
2040., 362.095, 2070., 366.92, 2100., 371.01, 2130., 375.47
2160., 380.015, 2190., 384.715, 2220., 390.08, 2250., 394.255
2280., 399.45, 2310., 404.195, 2340., 409.37, 2370., 413.495
2400., 418.93, 2430., 423.31, 2460., 428.415, 2490., 433.26
2520., 437.555, 2550., 442.665, 2580., 447.145, 2610., 452.855
2640., 457.48, 2670., 462.27, 2700., 467., 2730., 471.015
2760., 474.43, 2790., 478.265, 2820., 483.57, 2850., 487.085
2880., 491.65, 2910., 494.495, 2940., 498.14, 2970., 502.965
3000., 508.065, 3030., 511.005, 3060., 514.94, 3090., 518.26
3120., 522.345, 3150., 526.5, 3180., 528.775, 3210., 531.815
3240., 536.065, 3270., 540.065, 3300., 542.78, 3330., 546.01
3360., 548.875, 3390., 552.265, 3420., 555.695, 3450., 560.15
3480., 562.155, 3510., 566.13, 3540., 569.875, 3570., 572.395
3600., 575.115, 3630., 576.98, 3660., 580.54, 3690., 583.455
3720., 586.86, 3750., 589.24, 3780., 592.87, 3810., 595.195
3840., 597.775, 3870., 594.76, 3900., 595.445, 3930., 595.435
3960., 594.26, 3990., 596.335, 4020., 597.74, 4050., 593.06
4080., 593.135, 4110., 594.96, 4140., 596.025, 4170., 596.93
4200., 597.96, 4230., 597.26, 4260., 595.79, 4290., 596.21
4320., 596.18, 4350., 597.215, 4380., 597.3, 4410., 597.695
4440., 598.285, 4470., 599.37, 4500., 600.13, 4530., 598.21
4560., 598.45, 4590., 598.935, 4620., 598.485, 4650., 598.725
4680., 598.27, 4710., 599.58, 4740., 600.485, 4770., 599.695
4800., 600.765, 4830., 599.11, 4860., 599.405, 4890., 599.89
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5040., 600.56, 5070., 600.295, 5100., 600.68, 5130., 599.275
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6000., 600.165, 6030., 599.975, 6060., 599.93, 6090., 599.79
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6720., 599.555, 6750., 600.475, 6780., 600.72, 6810., 601.035
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6960.,	601.1,	6990.,	601.035,	7020.,	600.785,	7050.,	601.575
7080.,	601.45,	7110.,	601.655,	7140.,	601.625,	7170.,	601.575
7200.,	601.155,	7230.,	601.345,	7260.,	601.575,	7290.,	601.595
7320.,	601.555,	7350.,	602.485,	7380.,	602.855,	7410.,	603.055
7440.,	603.06,	7470.,	602.735,	7500.,	603.295,	7530.,	601.75
7560.,	600.14,	7590.,	600.015,	7620.,	600.06,	7650.,	600.83
7680.,	601.425,	7710.,	600.905,	7740.,	601.46,	7770.,	601.825
7800.,	601.905,	7830.,	601.595,	7860.,	601.875,	7890.,	601.84
7920.,	602.035,	7950.,	602.12,	7980.,	601.355,	8010.,	601.765
8040.,	602.025,	8070.,	602.07,	8100.,	602.615,	8130.,	602.775
8160.,	603.08,	8190.,	603.37,	8220.,	603.4,	8250.,	602.675
8280.,	601.81,	8310.,	601.96,	8340.,	602.395,	8370.,	602.41
8400.,	601.915,	8430.,	601.57,	8460.,	602.175,	8490.,	602.355
8520.,	602.785,	8550.,	602.61,	8580.,	602.275,	8610.,	602.58
8640.,	602.86,	8670.,	602.795,	8700.,	602.76,	8730.,	602.015
8760.,	602.6,	8790.,	602.91,	8820.,	602.615,	8850.,	603.115
8880.,	602.715,	8910.,	602.51,	8940.,	603.35,	8970.,	603.19
9000.,	602.865,	9030.,	603.64,	9060.,	603.,	9090.,	602.485
9120.,	602.005,	9150.,	602.065,	9180.,	602.115,	9210.,	602.04
9240.,	602.14,	9270.,	601.585,	9300.,	601.34,	9330.,	601.205
9360.,	601.475,	9390.,	601.62,	9420.,	601.835,	9450.,	601.655
9480.,	601.605,	9510.,	601.85,	9540.,	601.85,	9570.,	602.135
9600.,	601.93,	9630.,	602.41,	9660.,	602.285,	9690.,	602.455
9720.,	602.555,	9750.,	601.825,	9780.,	602.055,	9810.,	601.945
9840.,	602.39,	9870.,	602.455,	9900.,	602.06,	9930.,	602.485
9960.,	602.96,	9990.,	602.77,	10020.,	603.355,	10050.,	603.235
10080.,	603.415,	10110.,	603.415,	10140.,	603.195,	10170.,	603.07
10200.,	603.25,	10230.,	603.67,	10260.,	603.36,	10290.,	603.945
10320.,	603.8,	10350.,	603.96,	10380.,	602.82,	10410.,	602.87
10440.,	602.695,	10470.,	602.105,	10500.,	601.98,	10530.,	602.035
10560.,	601.815,	10590.,	601.695,	10620.,	602.285,	10650.,	602.645
10680.,	602.59,	10710.,	602.225,	10740.,	602.02,	10770.,	601.72
10800.,	602.03,	10830.,	602.215,	10860.,	602.595,	10890.,	602.45
10920.,	602.385,	10950.,	602.015,	10980.,	603.205,	11010.,	603.08
11040.,	603.26,	11070.,	603.665,	11100.,	604.34,	11130.,	603.875
11160.,	602.92,	11190.,	601.97,	11220.,	601.13,	11250.,	601.37
11280.,	601.115,	11310.,	601.545,	11340.,	601.495,	11370.,	601.73
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11640.,	602.515,	11670.,	602.875,	11700.,	602.885,	11730.,	603.29
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11880.,	603.16,	11910.,	603.525,	11940.,	603.275,	11970.,	603.275
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12360.,	603.41,	12390.,	603.36,	12420.,	603.23,	12450.,	603.06
12480.,	602.64,	12510.,	602.755,	12540.,	602.925,	12570.,	603.16
12600.,	603.45,	12630.,	603.85,	12660.,	603.83,	12690.,	603.88
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12840.,	604.73,	12870.,	603.815,	12900.,	602.71,	12930.,	601.915
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13080.,	601.825,	13110.,	601.715,	13140.,	602.31,	13170.,	602.555
13200.,	602.875,	13230.,	603.015,	13260.,	603.56,	13290.,	603.51
13320.,	603.245,	13350.,	602.98,	13380.,	602.895,	13410.,	602.98
13440.,	603.01,	13470.,	603.095,	13500.,	603.17,	13530.,	602.89
13560.,	602.99,	13590.,	603.405,	13620.,	603.29,	13650.,	603.065
13680.,	602.895,	13710.,	602.975,	13740.,	603.195,	13770.,	603.37
13800.,	603.76,	13830.,	603.895,	13860.,	604.345,	13890.,	604.735
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    14640.,     603.51,     14670.,     603.39,     14700.,    603.145,     14730.,    603.435
    14760.,    603.265,     14790.,    603.265,     14820.,    603.105,     14850.,      603.3
    14880.,    603.245,     14910.,    603.295,     14940.,     603.37,     14970.,     603.37
    15000.,     603.31,     15030.,     603.43,     15060.,     603.03,     15090.,     603.26
    15120.,    603.295,     15150.,     603.34,     15180.,     603.52,     15210.,    603.335
    15240.,     603.37,     15270.,    603.305,     15300.,    603.325,     15330.,     603.43
    15360.,    603.325,     15390.,    603.505,     15420.,     603.58,     15450.,      603.5
    15480.,    603.625,     15510.,     603.55,     15540.,    603.595,     15570.,      603.5
    15600.,    603.455,     15630.,    603.755,     15660.,    603.525,     15690.,     603.63
    15720.,     603.66,     15750.,    603.665,     15780.,    603.915,     15810.,     603.72
    15840.,     603.79,     15870.,     603.76,     15900.,     603.78,     15930.,     603.73
    15960.,    603.935
**
** MATERIALS
**
*Material, name="Lighweight Concrete Blocks"
*Conductivity
 0.33,600.
*Density
1400.,
*Latent Heat
48000.,107.,149.
*Specific Heat
700.,600.
*Material, name=Mortar
*Conductivity
 1.4,600.
*Density
1900.,
*Latent Heat
89000.,100.,113.
*Specific Heat
4000.,600.
**
** INTERACTION PROPERTIES
**
*Film Property, name=Cold
4., 600.
*Film Property, name=Hot
25., 600.
**
** PHYSICAL CONSTANTS
**
*Physical Constants, absolute zero=-273., stefan boltzmann=5.6697e-08
**
** PREDEFINED FIELDS
**
** Name: Initial temperature   Type: Temperature
*Initial Conditions, type=TEMPERATURE
_PickedSet10103, 20.
** ----------------------------------------------------------------
**
** STEP: Heat_transfer
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*Step, name=Heat_transfer, inc=100000
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*Heat Transfer, end=PERIOD, deltmx=10.
0.1, 15960., 0.0001, 15960.,
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** INTERACTIONS
**
** Interaction: Cold_faces
*Sfilm
External_cold_faces, F, 1., Cold
** Interaction: Hot_face
*Sfilm, amplitude=External
Hot_face, F, 1., Hot
** Interaction: Internal_cold_block_faces
*Sfilm, amplitude=External
Cold_blocks, F, 1., Cold
** Interaction: Internal_cold_mortar_faces
*Sfilm, amplitude=External
Cold_mortar, F, 1., Cold
** Interaction: Radiation_cold_faces
*Sradiate
External_cold_faces, R, 20., 0.7
** Interaction: Radiation_furnace
*Sradiate, amplitude=External
Hot_face, R, 1., 0.7
**
** OUTPUT REQUESTS
**
*Restart, write, frequency=0
**
** FIELD OUTPUT: F-Output-1
**
*Output, field, variable=PRESELECT
*Output, history, frequency=0
*End Step
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Thermal analysis data of big walls at 800ºC

```
*Amplitude, name=External, time=TOTAL TIME
0., 16., 30., 16., 60., 16.81, 90., 21.09
120., 30.07, 150., 42.31, 180., 55.74, 210., 67.59
240., 73.66, 270., 75.36, 300., 75.41, 330., 73.99
360., 75.23, 390., 79.21, 420., 86.64, 450., 95.9
480., 103.24, 510., 107.57, 540., 107.2, 570., 106.67
600., 107.56, 630., 111.12, 660., 117.56, 690., 125.04
720., 131.39, 750., 134.1, 780., 133.91, 810., 135.19
840., 140.75, 870., 148.63, 900., 155.29, 930., 160.21
960., 160.63, 990., 163.98, 1020., 168.97, 1050., 172.88
1080., 176.1, 1110., 179.38, 1140., 185.6, 1170., 191.89
1200., 197.94, 1230., 198., 1260., 200.2, 1290., 205.17
1320., 211.11, 1350., 216.94, 1380., 226.53, 1410., 235.6
1440., 239.46, 1470., 239.71, 1500., 238.76, 1530., 239.81
1560., 244.83, 1590., 252.48, 1620., 260., 1650., 265.18
1680., 269.49, 1710., 275.52, 1740., 278.27, 1770., 282.81
1800., 286.74, 1830., 289.26, 1860., 293.91, 1890., 301.52
1920., 307.03, 1950., 313.21, 1980., 318.32, 2010., 323.3
2040., 325.58, 2070., 331.27, 2100., 338.02, 2130., 341.51
2160., 345.09, 2190., 353.53, 2220., 355.25, 2250., 360.37
2280., 366.66, 2310., 367.41, 2340., 371.94, 2370., 374.18
2400., 384.3, 2430., 385.71, 2460., 390.3, 2490., 395.29
2520., 397.76, 2550., 405., 2580., 413.6, 2610., 416.61
2640., 417.88, 2670., 427.3, 2700., 432.45, 2730., 437.41
2760., 445.76, 2790., 445.07, 2820., 451.83, 2850., 455.14
2880., 460.77, 2910., 465.62, 2940., 468.3, 2970., 473.76
3000., 480.31, 3030., 483.56, 3060., 488.05, 3090., 491.04
3120., 492.67, 3150., 498.7, 3180., 502.18, 3210., 504.59
3240., 509.2, 3270., 514.74, 3300., 519.28, 3330., 522.36
3360., 527.54, 3390., 533.31, 3420., 535.59, 3450., 538.47
3480., 541.33, 3510., 545.22, 3540., 548.48, 3570., 553.38
3600., 558.4, 3630., 560.82, 3660., 564.28, 3690., 567.59
3720., 569.61, 3750., 575.18, 3780., 577.8, 3810., 580.16
3840., 584.61, 3870., 587.99, 3900., 590.35, 3930., 592.64
3960., 595.62, 3990., 599.57, 4020., 604.07, 4050., 605.82
4080., 608.87, 4110., 613.01, 4140., 616.42, 4170., 617.9
4200., 622.52, 4230., 624.5, 4260., 625.96, 4290., 630.8
4320., 632.8, 4350., 637.78, 4380., 638.09, 4410., 640.84
4440., 643.43, 4470., 647.38, 4500., 649.58, 4530., 652.31
4560., 656.3, 4590., 657.4, 4620., 661., 4650., 662.1
4680., 664.9, 4710., 668.2, 4740., 671.5, 4770., 673.
4800., 676.2, 4830., 679.7, 4860., 682.5, 4890., 683.9
4920., 686.8, 4950., 689.8, 4980., 692.2, 5010., 693.6
5040., 696., 5070., 698., 5100., 701.5, 5130., 704.
5160., 706.3, 5190., 709.2, 5220., 711.7, 5250., 714.2
5280., 716.2, 5310., 718.3, 5340., 720.1, 5370., 723.
5400., 725.7, 5430., 728.1, 5460., 730.1, 5490., 732.6
5520., 734.3, 5550., 737.1, 5580., 738.4, 5610., 740.9
5640., 743.8, 5670., 745.9, 5700., 748.2, 5730., 750.4
5760., 751.9, 5790., 753.9, 5820., 756.5, 5850., 758.7
5880., 760.5, 5910., 763.2, 5940., 765., 5970., 767.2
6000., 769.1, 6030., 771.3, 6060., 773.2, 6090., 774.7
6120., 777.1, 6150., 779.3, 6180., 781.6, 6210., 783.7
6240., 785.4, 6270., 787.6, 6300., 789.3, 6330., 791.
6360., 792.6, 6390., 794.7, 6420., 794.5, 6450., 794.1
6480., 796.4, 6510., 793.1, 6540., 792.8, 6570., 794.
6600., 795., 6630., 796., 6660., 794.4, 6690., 793.7
```

6720.,	794.,	6750.,	794.9,	6780.,	794.5,	6810.,	794.5
6840.,	794.8,	6870.,	795.3,	6900.,	795.9,	6930.,	796.7
6960.,	796.6,	6990.,	797.2,	7020.,	795.7,	7050.,	795.6
7080.,	796.,	7110.,	796.6,	7140.,	797.,	7170.,	797.
7200.,	795.5,	7230.,	795.2,	7260.,	794.9,	7290.,	795.2
7320.,	795.5,	7350.,	796.,	7380.,	796.,	7410.,	795.5
7440.,	796.2,	7470.,	796.4,	7500.,	796.8,	7530.,	796.7
7560.,	796.9,	7590.,	797.,	7620.,	797.8,	7650.,	795.6
7680.,	795.1,	7710.,	795.3,	7740.,	795.3,	7770.,	795.4
7800.,	795.6,	7830.,	794.8,	7860.,	794.9,	7890.,	795.5
7920.,	795.8,	7950.,	795.5,	7980.,	795.,	8010.,	795.4
8040.,	796.,	8070.,	795.8,	8100.,	796.1,	8130.,	796.
8160.,	796.3,	8190.,	796.9,	8220.,	797.,	8250.,	797.2
8280.,	797.5,	8310.,	798.,	8340.,	798.4,	8370.,	798.5
8400.,	798.7,	8430.,	799.,	8460.,	798.,	8490.,	798.2
8520.,	798.3,	8550.,	798.,	8580.,	798.4,	8610.,	798.7
8640.,	799.,	8670.,	799.3,	8700.,	799.3,	8730.,	798.6
8760.,	798.9,	8790.,	798.9,	8820.,	798.8,	8850.,	798.6
8880.,	798.8,	8910.,	799.2,	8940.,	799.4,	8970.,	798.8
9000.,	799.1,	9030.,	799.4,	9060.,	799.7,	9090.,	799.9
9120.,	798.6,	9150.,	797.9,	9180.,	798.1,	9210.,	798.4
9240.,	798.5,	9270.,	797.9,	9300.,	797.9,	9330.,	798.1
9360.,	798.5,	9390.,	798.2,	9420.,	798.2,	9450.,	798.2
9480.,	798.5,	9510.,	799.,	9540.,	798.7,	9570.,	798.6
9600.,	798.9,	9630.,	799.2,	9660.,	799.3,	9690.,	799.4
9720.,	799.4,	9750.,	799.8,	9780.,	800.2,	9810.,	799.7
9840.,	799.2,	9870.,	798.9,	9900.,	799.1,	9930.,	799.3
9960.,	799.1,	9990.,	798.9,	10020.,	799.,	10050.,	799.1
10080.,	799.2,	10110.,	799.4,	10140.,	799.1,	10170.,	799.2
10200.,	799.3,	10230.,	799.5,	10260.,	799.6,	10290.,	799.5
10320.,	799.8,	10350.,	800.,	10380.,	800.2,	10410.,	800.3
10440.,	800.1,	10470.,	800.3,	10500.,	799.5,	10530.,	798.9
10560.,	798.4,	10590.,	797.8,	10620.,	797.4,	10650.,	797.6
10680.,	797.4,	10710.,	797.,	10740.,	797.3,	10770.,	797.5
10800.,	797.4,	10830.,	797.3,	10860.,	797.2,	10890.,	797.5
10920.,	797.8,	10950.,	797.7,	10980.,	797.3,	11010.,	797.4
11040.,	797.1,	11070.,	797.7,	11100.,	798.2,	11130.,	798.4
11160.,	798.4,	11190.,	798.5,	11220.,	798.8,	11250.,	799.2
11280.,	799.5,	11310.,	799.2,	11340.,	799.3,	11370.,	799.9
11400.,	800.3,	11430.,	800.4,	11460.,	800.4,	11490.,	800.6
11520.,	801.2,	11550.,	801.5,	11580.,	801.4,	11610.,	801.4
11640.,	800.2,	11670.,	799.9,	11700.,	799.8,	11730.,	799.6
11760.,	799.5,	11790.,	799.8,	11820.,	799.7,	11850.,	799.8
11880.,	799.6,	11910.,	799.4,	11940.,	799.6,	11970.,	799.8
12000.,	799.8,	12030.,	799.5,	12060.,	799.4,	12090.,	799.8
12120.,	799.9,	12150.,	799.9,	12180.,	799.7,	12210.,	799.6
12240.,	800.1,	12270.,	800.1,	12300.,	800.,	12330.,	800.
12360.,	800.,	12390.,	800.1,	12420.,	800.4,	12450.,	800.1
12480.,	800.1,	12510.,	800.2,	12540.,	800.6,	12570.,	800.7
12600.,	800.7,	12630.,	800.5,	12660.,	800.7,	12690.,	800.9
12720.,	801.3,	12750.,	801.2,	12780.,	801.2,	12810.,	801.3
12840.,	801.7,	12870.,	801.8,	12900.,	801.8,	12930.,	801.7
12960.,	802.1,	12990.,	802.5,	13020.,	802.5,	13050.,	802.6
13080.,	800.7,	13110.,	800.6,	13140.,	800.4,	13170.,	799.8
13200.,	799.4,	13230.,	799.1,	13260.,	798.8,	13290.,	799.6
13320.,	799.1,	13350.,	798.5,	13380.,	799.4,	13410.,	799.3
13440.,	798.8,	13470.,	799.4,	13500.,	799.1,	13530.,	798.7
13560.,	798.6,	13590.,	799.8,	13620.,	799.5,	13650.,	799.3
13680.,	799.4,	13710.,	799.6,	13740.,	799.7,	13770.,	799.6
13800.,	799.5,	13830.,	799.8,	13860.,	800.,	13890.,	799.9

13920.,	799.9,	13950.,	799.9,	13980.,	800.1,	14010.,	800.2
14040.,	800.4,	14070.,	800.2,	14100.,	800.1,	14130.,	800.5
14160.,	800.7,	14190.,	800.7,	14220.,	800.5,	14250.,	800.5
14280.,	800.8,	14310.,	801.1,	14340.,	801.1,	14370.,	801.
14400.,	801.1,	14430.,	801.4,	14460.,	801.6,	14490.,	801.6
14520.,	801.5,	14550.,	801.7,	14580.,	802.,	14610.,	802.2
14640.,	802.2,	14670.,	802.2,	14700.,	802.5,	14730.,	802.8
14760.,	802.9,	14790.,	802.9,	14820.,	802.9,	14850.,	803.1
14880.,	803.4,	14910.,	802.6,	14940.,	801.9,	14970.,	801.7
15000.,	801.8,	15030.,	801.9,	15060.,	801.8,	15090.,	801.5
15120.,	801.4,	15150.,	801.6,	15180.,	801.7,	15210.,	801.5
15240.,	801.2,	15270.,	801.1,	15300.,	797.4,	15330.,	792.9
15360.,	796.3,	15390.,	803.7,	15420.,	801.1,	15450.,	798.9
15480.,	797.2,	15510.,	796.8,	15540.,	797.,	15570.,	797.
15600.,	796.8,	15630.,	796.6,	15660.,	796.4,	15690.,	796.5
15720.,	796.5,	15750.,	796.3,	15780.,	796.5,	15810.,	796.3
15840.,	796.4,	15870.,	796.5,	15900.,	796.9,	15930.,	796.6
15960.,	796.4,	15990.,	796.5,	16020.,	796.4,	16050.,	796.4
16080.,	796.5,	16110.,	796.4,	16140.,	796.5,	16170.,	796.5
16200.,	796.4,	16230.,	796.4,	16260.,	796.5,	16290.,	796.5
16320.,	796.6,	16350.,	796.4,	16380.,	796.5,	16410.,	796.4
16440.,	796.5,	16470.,	796.8,	16500.,	796.5,	16530.,	796.2
16560.,	797.,	16590.,	797.5,	16620.,	797.7,	16650.,	797.8
16680.,	797.9,	16710.,	798.3,	16740.,	798.6,	16770.,	798.4
16800.,	798.,	16830.,	797.8,	16860.,	797.9,	16890.,	797.8
16920.,	797.7,	16950.,	797.2,	16980.,	797.1,	17010.,	797.2
17040.,	797.2,	17070.,	797.,	17100.,	796.7,	17130.,	796.7
17160.,	796.8,	17190.,	797.,	17220.,	796.9,	17250.,	796.7
17280.,	796.8,	17310.,	796.8,	17340.,	797.1,	17370.,	796.8
17400.,	796.6,	17430.,	796.7,	17460.,	797.2,	17490.,	797.
17520.,	796.8,	17550.,	796.7,	17580.,	796.8,	17610.,	797.
17640.,	796.9,	17670.,	796.7,	17700.,	797.1,	17730.,	797.4
17760.,	797.4,	17790.,	797.2,	17820.,	796.9,	17850.,	796.8
17880.,	796.9,	17910.,	796.9,	17940.,	796.8,	17970.,	796.6
18000.,	796.9,	18030.,	797.1,	18060.,	797.,	18090.,	796.9
18120.,	796.7,	18150.,	797.,	18180.,	797.1,	18210.,	797.2
18240.,	797.3,	18270.,	796.8,	18300.,	796.9,	18330.,	797.1
18360.,	797.,	18390.,	796.9,	18420.,	797.,	18450.,	797.2
18480.,	797.2,	18510.,	797.2,	18540.,	797.2,	18570.,	797.
18600.,	797.,	18630.,	797.2,	18660.,	797.2,	18690.,	796.9
18720.,	796.8,	18750.,	797.1,	18780.,	797.2,	18810.,	797.1
18840.,	796.9,	18870.,	796.9,	18900.,	797.1,	18930.,	797.2
18960.,	797.,	18990.,	796.9,	19020.,	796.9,	19050.,	797.1
19080.,	797.2,	19110.,	797.1,	19140.,	796.9,	19170.,	797.
19200.,	797.1,	19230.,	797.2,	19260.,	797.1,	19290.,	796.9
19320.,	796.9,	19350.,	797.2,	19380.,	797.3,	19410.,	797.1
19440.,	797.,	19470.,	797.2,	19500.,	797.4,	19530.,	797.4
19560.,	797.2,	19590.,	797.1,	19620.,	797.4,	19650.,	797.6
19680.,	797.7,	19710.,	797.4,	19740.,	797.4,	19770.,	797.7
19800.,	797.8,	19830.,	797.7,	19860.,	797.6,	19890.,	797.5
19920.,	797.7,	19950.,	797.9,	19980.,	797.8,	20010.,	797.7
20040.,	797.7,	20070.,	798.,	20100.,	798.1,	20130.,	798.2
20160.,	797.9,	20190.,	798.,	20220.,	798.2,	20250.,	798.4
20280.,	798.3,	20310.,	798.1,	20340.,	798.3,	20370.,	798.6
20400.,	798.6,	20430.,	798.5,	20460.,	798.4,	20490.,	798.6
20520.,	798.8,	20550.,	798.8,	20580.,	798.7,	20610.,	798.9
20640.,	799.1,	20670.,	799.,	20700.,	799.1,	20730.,	798.3
20760.,	798.,	20790.,	798.,	20820.,	797.6,	20850.,	797.5
20880.,	797.1,	20910.,	797.4,	20940.,	797.5,	20970.,	797.4
21000.,	797.4,	21030.,	797.5,	21060.,	797.6,	21090.,	798.

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    21120.,      798.1,     21150.,      798.2,     21180.,      798.1,     21210.,      798.3
    21240.,      798.6,     21270.,      798.8,     21300.,      798.6,     21330.,      798.7
    21360.,      798.7,     21390.,       799.,     21420.,       799.,     21450.,      798.8
    21480.,      798.3,     21510.,      798.2,     21540.,       798.,     21570.,      797.9
    21600.,      797.5,     21630.,      797.1,     21660.,      797.2,     21690.,      797.4
    21720.,      797.6,     21750.,      797.2
**
** MATERIALS
**
*Material, name="Lighweight Concrete Blocks"
*Conductivity
 0.32,800.
*Density
1400.,
*Latent Heat
48000.,104.,145.
*Specific Heat
750.,800.
*Material, name=Mortar
*Conductivity
 1.4,800.
*Density
1900.,
*Latent Heat
89000.,100.,113.
*Specific Heat
4000.,800.
**
** INTERACTION PROPERTIES
**
*Film Property, name=Cold
4., 800.
*Film Property, name=Hot
25., 800.
**
** PHYSICAL CONSTANTS
**
*Physical Constants, absolute zero=-273., stefan boltzmann=5.6697e-08
**
** PREDEFINED FIELDS
**
** Name: Initial temperature   Type: Temperature
*Initial Conditions, type=TEMPERATURE
_PickedSet10103, 20.
** ----------------------------------------------------------------
**
** STEP: Heat_transfer
**
*Step, name=Heat_transfer, inc=100000
*Heat Transfer, end=PERIOD, deltmx=10.
0.1, 21750., 0.0001, 21750.,
**
** INTERACTIONS
**
** Interaction: Cold_faces
*Sfilm
External_cold_faces, F, 1., Cold
** Interaction: Hot_face
*Sfilm, amplitude=External
Hot_face, F, 1., Hot
```

```
** Interaction: Internal_cold_block_faces
*Sfilm, amplitude=External
Cold_blocks, F, 1., Cold
** Interaction: Internal_cold_mortar_faces
*Sfilm, amplitude=External
Cold_mortar, F, 1., Cold
** Interaction: Radiation_cold_faces
*Sradiate
External_cold_faces, R, 20., 0.7
** Interaction: Radiation_furnace
*Sradiate, amplitude=External
Hot_face, R, 1., 0.7
**
** OUTPUT REQUESTS
**
*Restart, write, frequency=0
**
** FIELD OUTPUT: F-Output-1
**
*Output, field, variable=PRESELECT
*Output, history, frequency=0
*End Step
```

APPENDIX E – Structural numerical input data

Structural analysis data of wallettes at 20ºC

```
*Element,type=Spring2,elset=BBBB10
11115,  Whole_block-2.22, Whole_block-3.2542
11116,  Whole_block-2.43, Whole_block-3.2563
11117,  Whole_block-2.64, Whole_block-3.2584
11118,  Whole_block-2.85, Whole_block-3.2605
11119,Whole_block-2.2542, Whole_block-3.22
11120,Whole_block-2.2563, Whole_block-3.43
11121,Whole_block-2.2584, Whole_block-3.64
11122,Whole_block-2.2605, Whole_block-3.85
11123,  Whole_block-3.42, Whole_block-1.2562
11124,  Whole_block-3.63, Whole_block-1.2583
11125,  Whole_block-3.84, Whole_block-1.2604
11126, Whole_block-3.105, Whole_block-1.2625
11127,Whole_block-3.2562, Whole_block-1.42
11128,Whole_block-3.2583, Whole_block-1.63
11129,Whole_block-3.2604, Whole_block-1.84
11130,Whole_block-3.2625, Whole_block-1.105
*Spring,nonlinear,elset=BBBB10
2,2
  -625., -0.0000667
  -563., -0.0000600
  -500., -0.0000533
  -438., -0.0000467
  -375., -0.0000400
  -313., -0.0000333
  -250., -0.0000267
  -188., -0.0000200
  -125., -0.0000133
   -63., -0.0000067
     0.,  0.0000000
     1.,  0.0000001
    30.,  0.0000032
    60.,  0.0000065
    91.,  0.0000097
   121.,  0.0000129
   151.,  0.0000161
   181.,  0.0000194
   211.,  0.0000226
   240.,  0.0000258
   269.,  0.0000290
   298.,  0.0000323
   326.,  0.0000355
   353.,  0.0000387
   379.,  0.0000419
   405.,  0.0000452
   429.,  0.0000484
   453.,  0.0000516
   475.,  0.0000548
   496.,  0.0000581
   515.,  0.0000613
   533.,  0.0000645
   550.,  0.0000677
   565.,  0.0000710
   578.,  0.0000742
```

```
   589.,  0.0000774
   599.,  0.0000806
   607.,  0.0000839
   614.,  0.0000871
   619.,  0.0000903
   623.,  0.0000935
   625.,  0.0000968
   625.,  0.0001000
*End Assembly
**
** MATERIALS
**
*Material, name=Lightweight_concrete
*Density
1463.,
*Elastic
 7e+08, 0.19
*Concrete Damaged Plasticity
20.,   0.1,  1.16, 0.667,    0.
*Concrete Compression Hardening
       4.95e+06,        0.
     5.033e+06,   7.8e-06
       5.19e+06,  1.33e-05
 5.34787e+06,  1.79e-05
 5.46627e+06,  6.64e-05
 5.57845e+06, 0.0001217
 5.68409e+06, 0.0001843
 5.78288e+06, 0.0002546
  5.8745e+06, 0.0003328
 5.95863e+06, 0.0004193
 6.03497e+06, 0.0005145
 6.10319e+06, 0.0006187
 6.16297e+06, 0.0007323
 6.21401e+06, 0.0008555
 6.25598e+06, 0.0009889
 6.28857e+06, 0.0011327
 6.31147e+06, 0.0012873
 6.32436e+06, 0.0014529
 6.32691e+06, 0.0016301
                  1.,  0.0202
*Concrete Tension Stiffening, type=GFI
632691.,10.
**
** PHYSICAL CONSTANTS
**
**Physical Constants, absolute zero=0., stefan boltzmann=0.
** ----------------------------------------------------------------
**
** STEP: Static_Analysis
**
*Step, name=Static_Analysis, nlgeom=YES, inc=1000000
*Static, stabilize=0.0002, allsdtol=0.05, continue=NO
0.001, 0.1, 1e-12, 0.1
**
** BOUNDARY CONDITIONS
**
** Name: BC-1 Type: Displacement/Rotation
*Boundary
_PickedSet4643, 2, 2
**
```

```
** LOADS
**
** Name: Load-1   Type: Pressure
*Dsload
_PickedSurf4644, P, 3.089e+06
**
** OUTPUT REQUESTS
**
*Restart, write, frequency=0
**
** FIELD OUTPUT: F-Output-1
**
*Output, field, variable=PRESELECT
**
** HISTORY OUTPUT: H-Output-1
**
*Output, history, variable=PRESELECT
*End Step
```

Structural analysis data of wallettes at 400ºC

```
*Element,type=Spring2,elset=BBBB10
11115,  Whole_block-2.22, Whole_block-3.2542
11116,  Whole_block-2.43, Whole_block-3.2563
11117,  Whole_block-2.64, Whole_block-3.2584
11118,  Whole_block-2.85, Whole_block-3.2605
11119,Whole_block-2.2542, Whole_block-3.22
11120,Whole_block-2.2563, Whole_block-3.43
11121,Whole_block-2.2584, Whole_block-3.64
11122,Whole_block-2.2605, Whole_block-3.85
11123,  Whole_block-3.42, Whole_block-1.2562
11124,  Whole_block-3.63, Whole_block-1.2583
11125,  Whole_block-3.84, Whole_block-1.2604
11126, Whole_block-3.105, Whole_block-1.2625
11127,Whole_block-3.2562, Whole_block-1.42
11128,Whole_block-3.2583, Whole_block-1.63
11129,Whole_block-3.2604, Whole_block-1.84
11130,Whole_block-3.2625, Whole_block-1.105
*Spring,nonlinear,elset=BBBB10
2,2
  -574., -0.0002000
  -517., -0.0001800
  -459., -0.0001600
  -402., -0.0001400
  -344., -0.0001200
  -287., -0.0001000
  -230., -0.0000800
  -172., -0.0000600
  -115., -0.0000400
   -57., -0.0000200
     0.,  0.0000000
     0.,  0.0000001
    28.,  0.0000097
    56.,  0.0000194
    83.,  0.0000290
   111.,  0.0000387
   139.,  0.0000484
   166.,  0.0000581
   193.,  0.0000677
   220.,  0.0000774
   247.,  0.0000871
   273.,  0.0000968
   299.,  0.0001065
   324.,  0.0001161
   348.,  0.0001258
   372.,  0.0001355
   394.,  0.0001452
   416.,  0.0001548
   436.,  0.0001645
   455.,  0.0001742
   473.,  0.0001839
   490.,  0.0001935
   505.,  0.0002032
   518.,  0.0002129
   530.,  0.0002226
   541.,  0.0002323
   550.,  0.0002419
   558.,  0.0002516
```

```
   564.,  0.0002613
   568.,  0.0002710
   572.,  0.0002806
   573.,  0.0002903
   574.,  0.0003000
*End Assembly
**
** MATERIALS
**
*Material, name=Lightweight_concrete
*Density
1463.,
*Elastic
3.86E+08, 0.19
*Concrete Damaged Plasticity
20.,   0.1,  1.16, 0.667,    0.
*Concrete Compression Hardening
 3.79900E+06,  0.0000000
 4.01200E+06,  0.0002982
 4.18200E+06,  0.0004083
 4.31800E+06,  0.0005963
 4.44400E+06,  0.0008073
 4.58500E+06,  0.0009839
 4.63250E+06,  0.0013750
           1,           0.035
*Concrete Tension Stiffening, type=GFI
463250.,10.
**
** PHYSICAL CONSTANTS
**
**Physical Constants, absolute zero=0., stefan boltzmann=0.
** ----------------------------------------------------------------
**
** STEP: Static_Analysis
**
*Step, name=Static_Analysis, nlgeom=YES, inc=1000000
*Static, stabilize=0.0002, allsdtol=0.05, continue=NO
0.001, 0.1, 1e-12, 0.1
**
** BOUNDARY CONDITIONS
**
** Name: BC-1 Type: Displacement/Rotation
*Boundary
_PickedSet4643, 2, 2
**
** LOADS
**
** Name: Load-1   Type: Pressure
*Dsload
_PickedSurf4644, P, 2.8806e+06
**
** OUTPUT REQUESTS
**
*Restart, write, frequency=0
**
** FIELD OUTPUT: F-Output-1
**
*Output, field, variable=PRESELECT
**
** HISTORY OUTPUT: H-Output-1
```

Structural analysis data of wallettes at 600ºC

```
*Element,type=Spring2,elset=BBBB10
11115,  Whole_block-2.22, Whole_block-3.2542
11116,  Whole_block-2.43, Whole_block-3.2563
11117,  Whole_block-2.64, Whole_block-3.2584
11118,  Whole_block-2.85, Whole_block-3.2605
11119,Whole_block-2.2542, Whole_block-3.22
11120,Whole_block-2.2563, Whole_block-3.43
11121,Whole_block-2.2584, Whole_block-3.64
11122,Whole_block-2.2605, Whole_block-3.85
11123,  Whole_block-3.42, Whole_block-1.2562
11124,  Whole_block-3.63, Whole_block-1.2583
11125,  Whole_block-3.84, Whole_block-1.2604
11126, Whole_block-3.105, Whole_block-1.2625
11127,Whole_block-3.2562, Whole_block-1.42
11128,Whole_block-3.2583, Whole_block-1.63
11129,Whole_block-3.2604, Whole_block-1.84
11130,Whole_block-3.2625, Whole_block-1.105
*Spring,nonlinear,elset=BBBB10
2,2
  -486., -0.0004333
  -437., -0.0003900
  -389., -0.0003467
  -340., -0.0003033
  -292., -0.0002600
  -243., -0.0002167
  -194., -0.0001733
  -146., -0.0001300
   -97., -0.0000867
   -49., -0.0000433
     0.,  0.0000000
     0.,  0.0000001
    24.,  0.0000210
    47.,  0.0000419
    70.,  0.0000629
    94.,  0.0000839
   117.,  0.0001048
   141.,  0.0001258
   164.,  0.0001468
   186.,  0.0001677
   209.,  0.0001887
   231.,  0.0002097
   253.,  0.0002306
   274.,  0.0002516
   295.,  0.0002726
   315.,  0.0002935
   334.,  0.0003145
   352.,  0.0003355
   369.,  0.0003565
   385.,  0.0003774
   401.,  0.0003984
   415.,  0.0004194
   427.,  0.0004403
   439.,  0.0004613
   449.,  0.0004823
   458.,  0.0005032
   466.,  0.0005242
   472.,  0.0005452
```

```
  477.,  0.0005661
  481.,  0.0005871
  484.,  0.0006081
  485.,  0.0006290
  486.,  0.0006500
*End Assembly
**
** MATERIALS
**
*Material, name=Lightweight_concrete
*Density
1463.,
*Elastic
2.420E+08, 0.19
*Concrete Damaged Plasticity
20.,   0.1,  1.16, 0.667,    0.
*Concrete Compression Hardening
 4.58800E+06, 0.0000000
 4.75000E+06, 0.0000064
 4.91700E+06, 0.0000320
 5.06000E+06, 0.0001258
 5.13000E+06, 0.0004270
 5.14000E+06, 0.0008986
 5.12000E+06, 0.0014554
 5.04000E+06, 0.0021826
          1., 0.0480000
*Concrete Tension Stiffening, type=GFI
514000.,10.
**
** PHYSICAL CONSTANTS
**
**Physical Constants, absolute zero=0., stefan boltzmann=0.
** ----------------------------------------------------------------
**
** STEP: Static_Analysis
**
*Step, name=Static_Analysis, nlgeom=YES, inc=1000000
*Static, stabilize=0.0002, allsdtol=0.05, continue=NO
0.001, 0.1, 1e-12, 0.1
**
** BOUNDARY CONDITIONS
**
** Name: BC-1 Type: Displacement/Rotation
*Boundary
_PickedSet4643, 2, 2
**
** LOADS
**
** Name: Load-1   Type: Pressure
*Dsload
_PickedSurf4644, P, 2.50746E+06
**
** OUTPUT REQUESTS
**
*Restart, write, frequency=0
**
** FIELD OUTPUT: F-Output-1
**
*Output, field, variable=PRESELECT
**
```

Structural analysis data of wallettes at 800ºC

```
*Element,type=Spring2,elset=BBBB10
11115,  Whole_block-2.22, Whole_block-3.2542
11116,  Whole_block-2.43, Whole_block-3.2563
11117,  Whole_block-2.64, Whole_block-3.2584
11118,  Whole_block-2.85, Whole_block-3.2605
11119,Whole_block-2.2542, Whole_block-3.22
11120,Whole_block-2.2563, Whole_block-3.43
11121,Whole_block-2.2584, Whole_block-3.64
11122,Whole_block-2.2605, Whole_block-3.85
11123,  Whole_block-3.42, Whole_block-1.2562
11124,  Whole_block-3.63, Whole_block-1.2583
11125,  Whole_block-3.84, Whole_block-1.2604
11126, Whole_block-3.105, Whole_block-1.2625
11127,Whole_block-3.2562, Whole_block-1.42
11128,Whole_block-3.2583, Whole_block-1.63
11129,Whole_block-3.2604, Whole_block-1.84
11130,Whole_block-3.2625, Whole_block-1.105
*Spring,nonlinear,elset=BBBB10
2,2
  -123., -0.0005867
  -111., -0.0005280
   -98., -0.0004693
   -86., -0.0004107
   -74., -0.0003520
   -62., -0.0002933
   -49., -0.0002347
   -37., -0.0001760
   -25., -0.0001173
   -12., -0.0000587
     0.,  0.0000000
     0.,  0.0000001
     6.,  0.0000284
    12.,  0.0000568
    18.,  0.0000852
    24.,  0.0001135
    30.,  0.0001419
    36.,  0.0001703
    41.,  0.0001987
    47.,  0.0002271
    53.,  0.0002555
    59.,  0.0002839
    64.,  0.0003123
    69.,  0.0003406
    75.,  0.0003690
    80.,  0.0003974
    84.,  0.0004258
    89.,  0.0004542
    93.,  0.0004826
    98.,  0.0005110
   101.,  0.0005394
   105.,  0.0005677
   108.,  0.0005961
   111.,  0.0006245
   114.,  0.0006529
   116.,  0.0006813
   118.,  0.0007097
   119.,  0.0007381
```

```
  121.,  0.0007665
  122.,  0.0007948
  122.,  0.0008232
  123.,  0.0008516
  123.,  0.0008800
*End Assembly
**
** MATERIALS
**
*Material, name=Lightweight_concrete
*Density
1463.,
*Elastic
1.730e+07, 0.19
*Concrete Damaged Plasticity
20.,   0.1,  1.16, 0.667,    0.
*Concrete Compression Hardening
 1.96000E+06, 0
 2.07000E+06, 0.0001250
 2.15000E+06, 0.0011250
 2.19833E+06, 0.0025208
 2.19500E+06, 0.0045625
 2.17300E+06, 0.0068375
 2.08000E+06, 0.0100000
 1.97167E+06, 0.0133542
 1.80500E+06, 0.0174375
 1.62000E+06, 0.0217500
 1.41000E+06, 0.0263750
        1.,, 0.0580000
*Concrete Tension Stiffening, type=GFI
219833.,10.
**
** PHYSICAL CONSTANTS
**
**Physical Constants, absolute zero=0., stefan boltzmann=0.
** ----------------------------------------------------------------
**
** STEP: Static_Analysis
**
*Step, name=Static_Analysis, nlgeom=YES, inc=1000000
*Static, stabilize=0.0002, allsdtol=0.05, continue=NO
0.001, 0.1, 1e-12, 0.1
**
** BOUNDARY CONDITIONS
**
** Name: BC-1 Type: Displacement/Rotation
*Boundary
_PickedSet4643, 2, 2
**
** LOADS
**
** Name: Load-1   Type: Pressure
*Dsload
_PickedSurf4644, P, 6.269E+05
**
** OUTPUT REQUESTS
**
*Restart, write, frequency=0
**
** FIELD OUTPUT: F-Output-1
```

```
**
*Output, field, variable=PRESELECT
**
** HISTORY OUTPUT: H-Output-1
**
*Output, history, variable=PRESELECT
*End Step
```